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This plan, submitted annually, describes the U.S. initiatives carried out by Federal Agencies which either directly support or contribute to the goals of the World Weather Program. The lessons learned and application of the results from the recently concluded Data Systems Tests are highlighted in Section I. These tests were designed as controlled investigations into the operation of the observing, data communications and data processing systems likely to be available for FGGE--the Global Weather Experiment. Section 2 discusses the relationship of our national activities with those of other nations cooperating in the World Weather Program. Section 3 provides specific information on the U.S. planned efforts which contribute to or directly support the World Weather Program goals in FY 1977. A fiscal summary of these programs is contained in the concluding section. (Sinha - OEIS)

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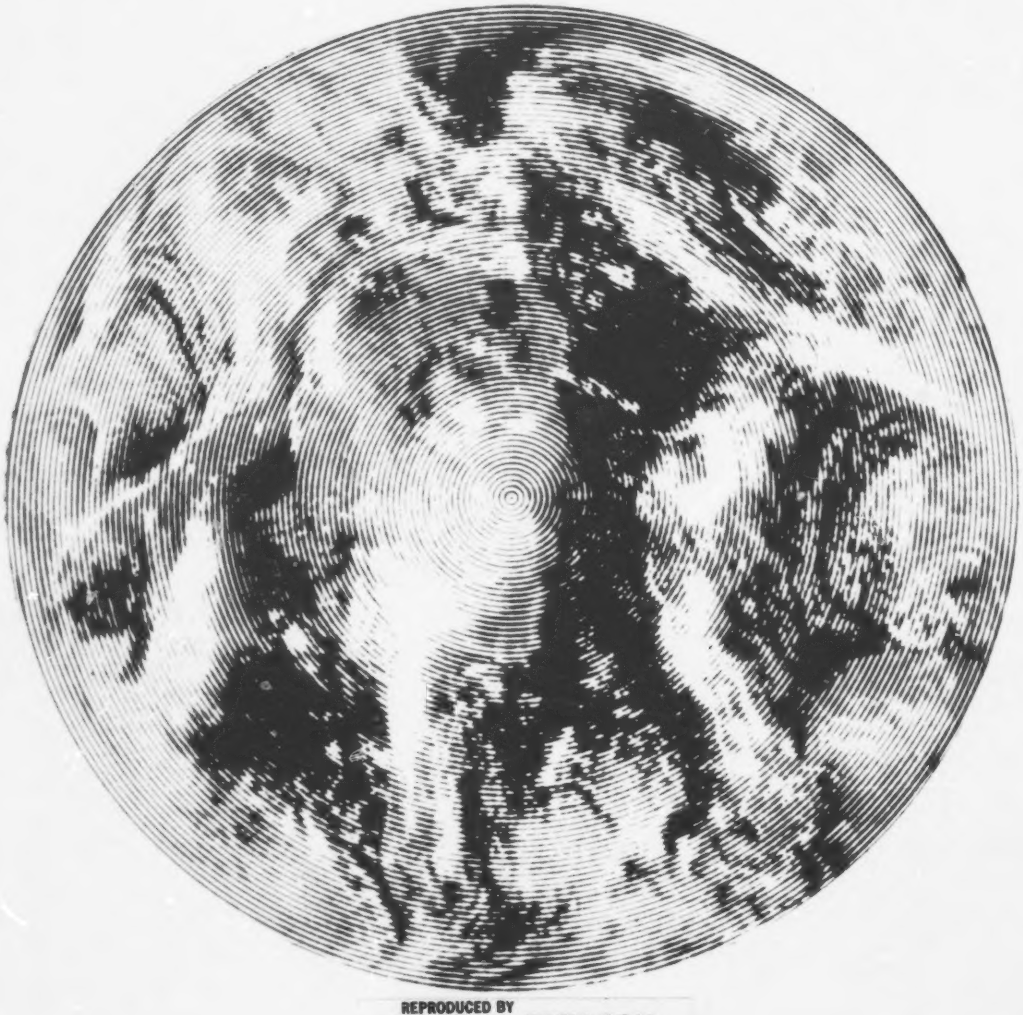
WORLD WEATHER PROGRAM

PLAN FOR FISCAL YEAR 1978



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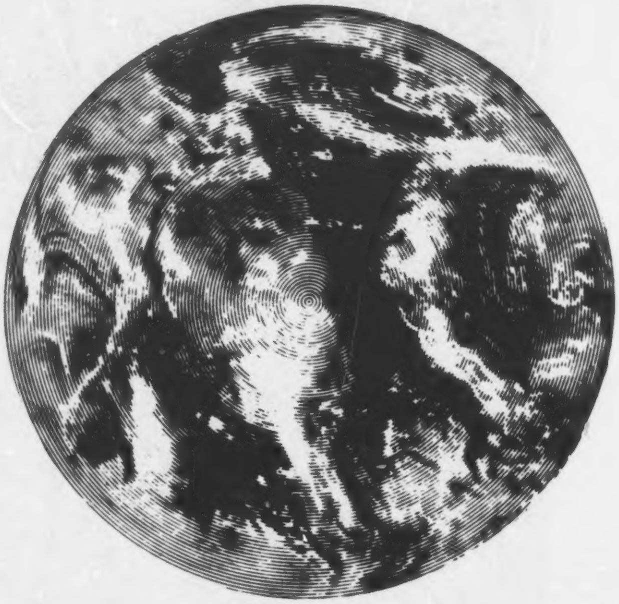

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NATIONAL SCIENCE FOUNDATION

Can drought be forecast? Will all reservoirs in the West look like this? The Global Weather Experiment has as one goal, the provision of a data base so questions on the limits of forecasting can be examined.

To the Congress of the United States:

The memory of the severe winter of 1976-1977 in the eastern United States and its effects on our people and the national economy is still fresh in our minds. The continuing drought in the western United States is impacting not only agriculture and power generation but even basic community water supplies. Droughts, floods and freezes in the USSR, the African Sahel, the Indian subcontinent and Brazil in recent years have unsettled world markets and inflicted misery and often death upon untold numbers of people.

Senate Concurrent Resolution 67 of the 90th Congress dedicated the United States to participate in the World Weather Program in order to develop improved worldwide weather observations and services and to conduct a comprehensive program of research to extend our understanding and prediction of global weather and climate variations. I am pleased to transmit, in accordance with that Resolution, this annual World Weather Program Plan that describes significant activities and accomplishments and outlines the planned participation of Federal agencies for the coming fiscal year. The progress already achieved in this vital program demonstrates that we truly can do something about the weather.

JIMMY CARTER

THE WHITE HOUSE,
September 1977

Foreword

The Senate of the United States passed Concurrent Resolution 67 in 1968 committing this country to the World Weather Program, an international effort whose goals are to understand the atmosphere and to extend the time, range and scope of weather predictions. The U.S. contribution to the World Weather Program has three basic components: the World Weather Watch (WWW), the Global Atmospheric Research Program (GARP), and the Systems Design and Technological Development Program. This Plan, submitted annually, describes the U.S. initiatives carried out by Federal Agencies which either directly support or contribute to the goals of the World Weather Program.

The lessons learned and application of the results from the recently concluded Data Systems Tests are highlighted in Section I. These tests were designed as controlled investigations into the operation of the observing, data communications and data processing systems likely to be available for FGGE -- The Global Weather Experiment. Emphasis was placed on examining the potential performance of new satellite systems and the compatibility of new data from those systems with current data processing and archiving techniques.

Section 2 discusses the relationship of our national activities with those of other nations cooperating in the World Weather Program. This section includes description of the updated international four-year plan for implementation of the observing, telecommunications, and data processing functions of the WWW; the assistance to developing countries so they may both benefit from and contribute to the program; the design and management activities for The Global Weather Experiment to take place in 1978-1979; and systems design and technological activities for both the WWW and GARP in observing systems, such as new satellites and their sensor systems, windfinding systems, surface-based remote sensing systems, data buoys, and automatic meteorological observing systems.

Section 3 provides specific information on the U.S. planned efforts which contribute to or directly support the World Weather Program goals in FY 1977. These plans include maintaining a two-spacecraft, operational geostationary satellite system; procuring and installing spacecraft and ground equipment for the next generation polar-orbiting satellite system, the TIROS-N; improving programs to monitor atmospheric constituents to determine their influence on climate and their impact upon the quality of the environment; and continuing assistance to developing nations for their participation in the WWW. GARP plans include the further analysis of data from the Data Systems Tests and applying these analyses to the plans for conducting The Global Weather Experiment; purchasing equipment for FGGE and initiating the build-up phase. GARP research activities are continuing in numerical modeling of the global atmosphere to determine the ultimate limit of weather predictability, assessing the effect of man's activities on climate, and designing an optimum composite meteorological observing system for routine numerical weather prediction.

A fiscal summary of these programs is contained in the concluding section.

All FY 1978 fiscal data in this plan are reflected in the President's budget, and the data shown here should be used for planning purposes only. The scheduling and implementation of the U.S. programs after FY 1978 in support of the World Weather Program are subject to additional analysis and further judgment.

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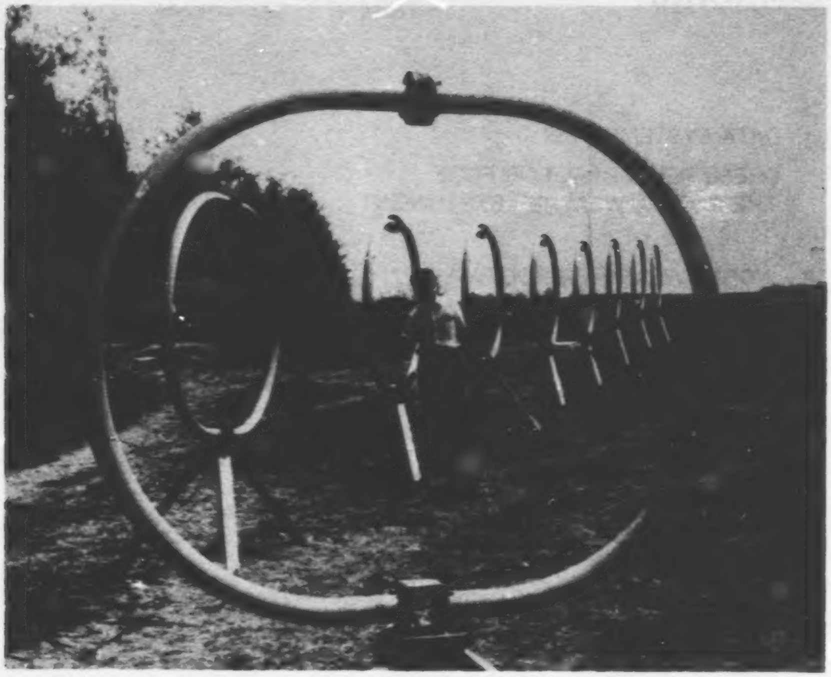


The GARP Atlantic Tropical Experiment conducted in 1974 involved ships, scientists, satellites and aircraft from 76 nations in an extensive probe of a 20 million square mile area west of Senegal to determine the effects of the tropical atmosphere on global weather. This antenna array at Yoff Airport, Dakar, Senegal, was a vital link in coordinating the operations of the scientific force.

1. Data Systems Test: Dress Rehearsal for FGGE – The Global Weather Experiment

■

INTRODUCTION

A century of international cooperation and a decade of building the World Weather Watch (WWW) is about to be culminated in a global experiment lasting a year and which will be conducted by the 144 Member nations of the World Meteorological Organization (WMO). Formed in 1873, the International Meteorological Organization persisted as the mechanism to facilitate the exchange of weather data and cooperative services until it was absorbed into the United Nations structure as the WMO. In the early sixties the WMO conceived the World Weather Watch as a means of greatly improving weather services by capitalizing on the technological developments which were being paced by space technology. Deeper and more direct involvement of WMO Members in the international collection, exchange and processing of weather data is one major result of the WWW. In turn, this involvement generated greater demands for better and longer period forecasts, and more extensive data bases.

To help satisfy these demands a global experiment was designed within the Global Atmospheric Research Program (GARP) to investigate forecast capabilities and to better define the data bases needed from the WWW. The First GARP Global Experiment (FGGE) -- The Global Weather Experiment came into being. The Operational Year will last from December 1978 to December 1979 and will be preceded by twelve months of assembling and testing the components.

For that year beginning in December 1978, the operational World Weather Watch will be augmented in order to obtain the most extensive weather and climate data base ever assembled. The earth's ocean-atmosphere system will be probed by sensors mounted on satellites, aircraft, balloons, ships, buoys and at land stations. Some of the sensors and platforms are being specially designed for the experiment and represent significant advances in observing techniques. Networks using existing techniques are being expanded. FGGE -- The Global Weather Experiment -- will provide the basis for evaluating both the adequacy of the current WWW observing, communications and processing systems and the practicality of making longer term, global forecasts.

Congressional action a decade ago provided the impetus for this most comprehensive weather experiment ever to be conducted. In May 1968 Senate Concurrent Resolution 67 committed the United States to the World Weather Program encompassing:

- The World Weather Watch
- A program for developing new observation, communication, and data processing techniques
- Research on the atmospheric system
- Training for U.S. scientists and technicians, and
- Training for people from other nations.

Given this congressional impetus, the World Weather Program for research on the atmospheric system has provided the vehicle for bringing together the scientific talent, ideas and resources which comprise the Global Atmospheric Research Program (GARP).

The major objectives of GARP are (1) to extend the range, scope, and accuracy of weather forecasts, and (2) to understand the physical basis of climate and climatic fluctuations. At first, subelements of these broad objectives were identified and examined in regional field experiments such as the Barbados Oceanographic and Meteorological Experiment (BOMEX) and the GARP Atlantic Tropical Experiment (GATE). With the experience of these and similar experiments as a base, a global weather experiment, known as the First GARP Global Experiment (FGGE), was conceived as a focal point in the pursuit of the first GARP objective -- improved forecasts.

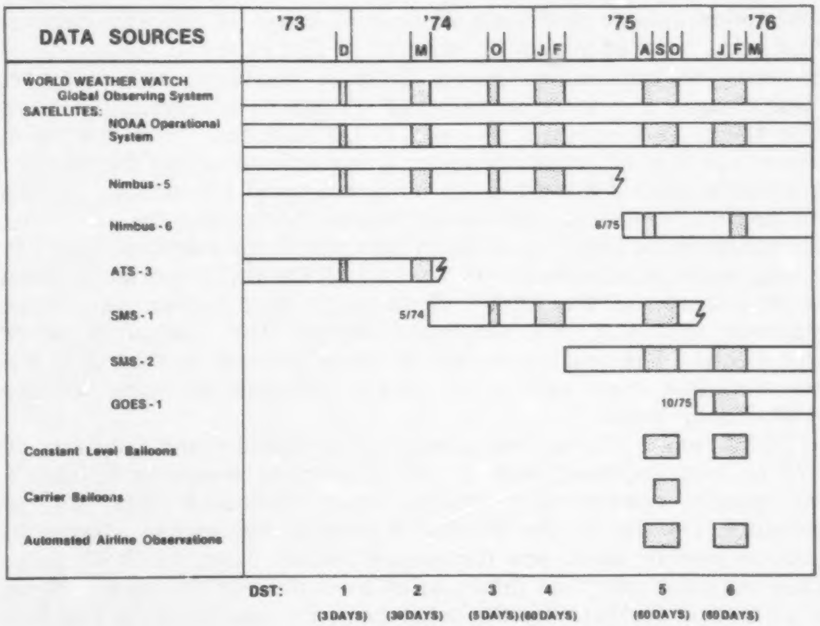
A unique combination of observing systems will be used for The Global Weather Experiment. The 700 upper air, 3500 surface synoptic, 6000 ships, and several thousand commercial aircraft comprising the bulk of the surface-based World Weather Watch Global Observing System (GOS) will be combined with the following array of observing systems:

- Four operational polar orbiting meteorological satellites
- Five operational geostationary meteorological satellites
- Two research meteorological satellites
- Up to fifty specially equipped ships for upper air sounding in the tropics
- Approximately 300 constant level balloons for tropical wind measurements
- Approximately 300 drifting buoys, largely in the Southern Hemisphere
- Approximately 20 specially equipped commercial aircraft for measurements of wind and temperature at flight level, and
- Approximately ten dedicated aircraft flying designated tracks over the oceans, dropping sounding instruments to obtain information from flight level to the surface.

All of the 144 Members of the WMO will participate in the WWW observing portion of The Global Weather Experiment and upwards of twenty members will provide the observing systems unique to FGGE.

An important lesson learned from BOMEX and GATE was the need for limited but realistic simulations prior to attempting the larger experiment. The concept of conducting a series of Data Systems Tests (DST) was therefore developed. These tests were designed to serve as a precursor for FGGE and to provide insight into the suitability of the existing meteorological observing systems, data processing and distribution facilities, and data utilization in analysis and forecast models. Strengths and weaknesses found during the DSTs could then be examined and FGGE plans changed accordingly.

The GARP Project Office of the National Aeronautics and Space Administration (NASA) was charged with the planning, implementation, and operational management of the Data Systems Tests. The basic approach was to use current operational satellites, conventional meteorological data, and data from research satellites to approximate the elements of the proposed observation system for FGGE. These data have now been collected and processed for application in numerical models to provide a full test of the proposed FGGE system from data collection to forecast



During the Data Systems Tests currently available observing systems were used to simulate the data to be available during The Global Weather Experiment. Various periods were set aside to examine the data from these systems separately and in combination.

preparation. An extremely valuable by-product of the DST has been the collection of global sets of meteorological data better than any that have been obtained previously.

DST HIGHLIGHTS - The Early Experiments

Six Data Systems Tests of varying lengths, purposes, and participation have been conducted. Of these, the first four were more limited tests of individual subsystems. The final two DST periods consisted of comprehensive tests of the entire system. In the first two tests, the conventional observations and data from the operational satellite system operated by the National Oceanic and Atmospheric Administration (NOAA) were supplemented with sounding retrievals (atmospheric temperature profiles) from the Nimbus-5 experimental satellite. The operational satellite data included sea surface temperatures, sounding retrievals from the NOAA-2 and -3 spacecraft, and winds obtained by tracking clouds on sequences of pictures from the geosynchronous ATS-3 satellite. For the first time, data from infrared and microwave sounding systems on Nimbus-5 were combined in an effort to simulate the sounding systems expected to be available during FGGE.

A 5-day test, DST-3, was conducted in October, 1974 primarily to examine the performance of an interactive computer system developed at the University of Wisconsin to produce high density wind fields in near real time at several levels in the atmosphere. Wind data are obtained at several facilities by tracking cloud elements on successive images from a geostationary satellite. These images are normally taken at 30 minute intervals, but have been taken as frequently as each 7 1/2 minutes. The Wisconsin system has the added flexibility of being able to adjust the number of winds produced for different meteorological situations. During this period, the development of automated techniques for producing operational wind fields by NOAA's National Environmental Satellite Service were accelerated. As a result of the DST experience, both the Wisconsin and the NOAA cloud-track wind system have been improved and will be employed during The Global Weather Experiment. The real advantage of these systems is that data are now available over vast areas where conventional data sources simply do not exist.

DST-4 was a 60-day test conducted in January and February of 1975 to test improvements in the processing programs to obtain atmospheric temperature profiles from Nimbus-5 data and to introduce the use of the Nimbus-5 passive microwave images to produce weekly mean sea ice concentration maps for both polar areas and daily rain rate information over the world oceans. Here, as with wind derivations, the procedures for sea ice maps and rain rate information evaluated during the DSTs led to their being incorporated into The Global Weather Experiment as well as accelerating their use in operational programs.

DSTs Five and Six - Full System Tests

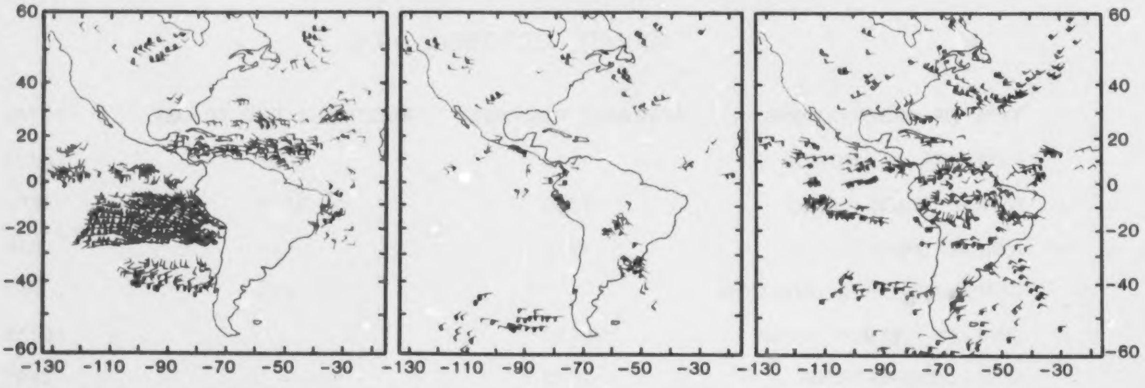
The last two tests, DST-5 and -6 were each of 60 days duration and were conducted under summer and winter conditions anticipating the two Special Observing Periods planned for The Global Weather Experiment in January/February and May/June, 1979. Atmospheric temperature sounding data from the Nimbus-6 experimental satellite were processed for 30 days out of each of the 60-day periods. These two tests produced the most comprehensive sets of global meteorological data yet assembled.

The new data sources introduced during the DST-5 and -6 test periods included:

- Constant Level Balloons - Reports were collected on temperature and wind from approximately 120 constant level (nominally 45,000 feet) balloon platforms in the tropical latitudes. These balloons were part of the Tropical Wind, Energy Conversion and Reference Level Experiment (TWERLE) flown in conjunction with the Nimbus-6 data collection system.
- Carrier Balloons - During DST-5, a complete systems test was carried out with thirteen constant level (nominally 85,000 feet) carrier balloons being launched near the equator. Each balloon carried 64 dropsondes which transmitted temperature, humidity and wind information back to the carrier balloon as they fell.

TYPICAL EXAMPLES OF WIND SETS PRODUCED AT UNIVERSITY OF WISCONSIN

DURING THE AUGUST / SEPTEMBER DATA SYSTEMS TEST



LOW (900-700mb) **MIDDLE (600-400mb)** **HIGH (300-200mb)**

This figure shows a typical wind data set generated by the University of Wisconsin during a Data Systems Test. This set, for 2000GMT on August 25, 1975, was one of four produced daily during the DST.

- Airline Observations - An agreement was reached with a number of foreign airlines whereby in-flight meteorological data were obtained from specially-equipped commercial aircraft. As part of the Aircraft Integrated Data System (AIDS) tape recorders on wide-bodied jets (B-747 and DC-10) recorded flight-level wind, temperature, altitude, and position. These tapes were processed immediately after the flight and the data were sent both directly to research centers and over the Global Telecommunications System (GTS) of the World Weather Watch.
- Earth Radiation Budget - Products from the Nimbus-6 Earth Radiation Budget (ERB) experiment include tables of daily total and spectral solar irradiance as well as monthly mean global maps of the terrestrial flux of longwave radiation, earth albedo and net radiation.

In terms of completeness, the DST-5 and -6 data sets will not be surpassed until FGGE itself. Nearly three to five times as much satellite derived wind and temperature profile data were obtained during the DST as would be obtained routinely.

The National Meteorological Center (NMC) of NOAA collected and merged the data from the various sources into internally consistent global data sets. In this regard, their role in the DST paralleled that of the Space-based and Special Observing System Data Center planned for FGGE. NMC also used the merged data sets to produce global grid point analyses of selected meteorological parameters at 6 and 12 hour time intervals. These data sets have been distributed to selected scientific investigators at NMC, NASA's Goddard Institute for Space Studies (GISS), the National Center for Atmospheric Research, the University of California at Los Angeles

AVERAGE DAILY DATA COUNTS DURING DST-5,
AUGUST-OCTOBER, 1975

TYPE OF OBSERVATIONS	AVAILABLE ROUTINELY	ADDITIONAL DUE TO DST	TOTAL
SATELLITE SOUNDINGS	1113	5008	6121
CLOUD TRACK WINDS	1326	3653	4979
AIRLINE (AIDS)	1279	647	1926
CONSTANT LEVEL BALLOON	–	262	262
SURFACE OBSERVATIONS	16133	–	16133
SHIP OBSERVATIONS	2445	–	2445
RAWINSONDES	2518	–	2518

One of the goals of The Global Weather Experiment is to increase the data available to processing centers by encouraging and fostering improvements to the World Weather Watch. For DST-5, August to October 1975, some kinds of data were increased by three to five times over that routinely available.

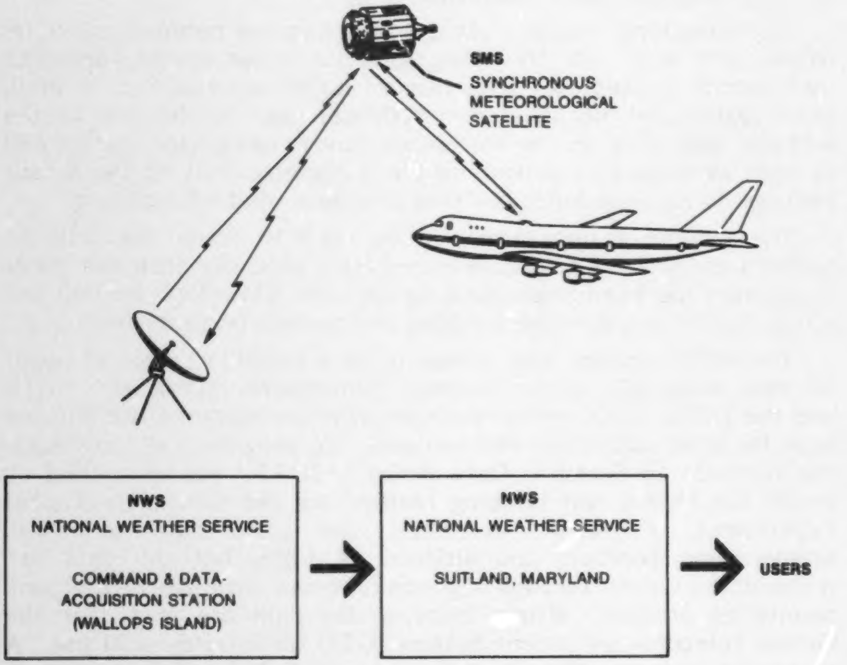
and NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) for research studies on FGGE-related problems of observational network design, data analysis and management, and forecast models.

■ LESSONS LEARNED-LESSONS APPLIED

The important aspect of the Data Systems Tests has been the insight gained into the central problems of conducting The Global Weather Experiment: the adequacy of the composite observing system, the data acquisition and processing plans and the utilization of the data in numerical forecast models. This insight has been vital to proper planning for the experiment. As a result of the DST experience, significant changes have been made in both the planned observing program and the procedures for managing the data flow.

ASDAR

AIRCRAFT TO SATELLITE DATA RELAY


SMS
SYNCHRONOUS
METEOROLOGICAL
SATELLITE
NWS
NATIONAL WEATHER SERVICE
COMMAND & DATA-ACQUISITION STATION
(WALLOPS ISLAND)
NWS
NATIONAL WEATHER SERVICE
SUITLAND, MARYLAND
USERS

The Aircraft to Satellite Data Relay system assembles meteorological data from instrumentation on-board commercial wide-bodied jets and relays the information to ground stations through geostationary meteorological satellites. Seven ASDAR units will be operating in late 1977 and additional units will be purchased for use during The Global Weather Experiment.

Examination of the quality of the Nimbus-6 derived atmospheric temperature profiles during DST-5 and -6 has led to a number of conclusions. First, the temperature data had a consistency and compatibility with operational analyses surpassing that from previous sounding systems. Second, problems encountered include the existence of local biases between satellite and rawindsonde data and the tendency for satellite data to underestimate the amplitude of major weather features. These deficiencies are being investigated in depth prior to the start of FGGE. The performance of the Nimbus-6 sounding system during the DSTs gave added support to the decision to employ that system on the TIROS-N satellites during FGGE.

The need for upper level wind information over the tropics emerged as the principal deficiency to be overcome. The need for additional tropical wind data was followed closely by the need for wind data in the Southern Hemisphere.

In the tropics, the Carrier Balloon System was thoroughly tested and judged too risky for deployment during The Global Weather Experiment. Plans were dropped for its use during the experiment. In its place changes were made in the use of dedicated ships and aircraft to obtain upper level wind data.

Approximately ten aircraft used for weather reconnaissance by NOAA and DOD will fly along selected ocean tracks, dropping instruments at half-hour intervals to obtain observations of wind, temperature and humidity from altitudes near 30,000 feet to the surface. Signals from the worldwide Omega navigation system will be used as a basis to determine the horizontal drift of the sensor package on its parachute, and thus to obtain wind information.

The Omega system also will be used to track the drift of balloons and trailing sensors released from specially equipped ships. A contract has been negotiated through the WMO for a Finnish and a U.S. firm to produce the tracking and balloon-borne systems.

The AIDS concept was proven to be a valuable source of upper air data, expecially in the Southern Hemisphere, during both GATE and the DSTs. AIDS units recorded wind and temperature data on tape for later collection and analysis. To provide real-time data, the Aircraft to Satellite Data Relay (ASDAR) was developed by NASA for NOAA and is being readied for use during the Global Experiment. ASDAR assembles the same data on wind, temperature, position, and altitude as AIDS, but the data are transmitted hourly through a geosynchronous satellite to a ground monitoring station. Within minutes, the data are sent over the Global Telecommunications System (GTS) for international use. A prototype system is flying on a commercial B-747 and six additional units will be installed by January 1978. Overall, some 20 ASDAR units are planned for installation on commercial aircraft for use during FGGE.

Data Management

Assembling the data from the DSTs has convinced all participants that the new types and sources of data require improved techniques to manage the data flow. Significant errors could be introduced into the data base without adequate control, and these errors might not be found until substantial efforts had been made to actually use the data. The two key implications of the DSTs concerning the data management for FGGE are:

(1) greatly improved monitoring of the observing and telecommunications systems is needed, and
(2) an operational readiness evaluation of the data flow must be made prior to the start of the FGGE.

Monitoring

A central objective of The Global Weather Experiment is to obtain the best possible global data base. During the operational year, particularly during the two, 60-day Special Observing Periods,

Small scale cumulus clouds in the tropics represent physical processes smaller than the grid size of global or hemispheric numerical forest models, but they have an important impact on the quality of the forecasts. One objective of the Data Systems Tests was to examine better ways of representing smaller scale processes.

additional observations will be taken by selected WWW stations to obtain an even larger amount of data. To ensure that all of these reports flow through the system efficiently, a worldwide monitoring program is needed to identify when reports are not received or are received improperly. When possible, messages will be sent asking for the data to be retransmitted. Otherwise, reports will be requested by mail and later merged into the data base. Monitoring is also needed to identify sources of major or persistent losses of data so that the problem can be corrected, eliminating the time-consuming use of mail. The United States as a result of its DST experiences, has been a prime mover in developing a WWW Monitoring Plan. A pilot project has been started with Brazil as a first step toward implementing the plan.

Operational Readiness ■

The FGGE data management plan is based largely on the experience gained in processing the DST data. Briefly, area sub-centers have been established to collect the WWW data, correct identifiable errors, request new transmissions of erroneous or missing data and to assemble the data in internationally agreed formats on magnetic tape. This work is done in real-time as the data are transmitted. Unique processing centers have been established to receive and process data from the FGGE Special Observing Systems. Data from the sub-centers, special processing centers and late reports will be merged into the basic observational data set for FGGE. This merging will be done routinely and within 6 months of data acquisition. The build-up phase for The Global Weather Experiment begins in the Fall 1977. Beginning in June 1977, portions of the FGGE data management plan were implemented to begin tests of national and international interfaces. The production of FGGE data tapes will begin in January 1978. This allows a full year to identify and correct problems before the experiment begins.

Data Utilization ■

The formative stages of GARP planning were based upon advances which had been made in three areas: (1) An increased scientific understanding of those atmospheric processes that produce weather, coupled with the development of analytic models of the atmosphere; (2) the development of faster and more sophisticated computers; and (3) the emergence of the meteorological satellite as a powerful data-gathering tool. From initial studies of the utilization of data acquired during the DST periods, it has become clear that the analysis problem is more complex than had been previously thought and that significantly improved analysis techniques are needed as precursors to studies of the forecast problem.

Work is underway to expand DST research studies using the DST-5 and -6 global data sets to examine the adequacy of the observing system and the impact of its various components, evaluate and improve the methods for deriving meteorological parameters from sensor data, develop improved methods for assimilating satellite data and improve the forecast models. As one example of the problem faced by people using the data, the observing systems over the years have been structured to obtain new data on a global basis at regular time intervals such as 6 or 12 hours. Satellite data, on the other hand, are continuously being recorded along the orbital track. The same is true of AIDs or ASDAR data from aircraft. Similarly, radars and automatic weather stations can provide high volumes of data obtained at irregular intervals. The problem is to merge the continuous satellite and volumes of other data with the discreet blocks of conventional data in an optimal fashion so as to minimize the resultant forecast error.

In the case of the models themselves, the areas where additional improvement is required include the representation in the analyses of physical processes smaller than the grid scale of the model, coupling of the atmospheric models with ocean models, and improved resolutions both in the vertical and horizontal. The continued research to be carried out with the DST data sets is aimed at overcoming the known deficiencies of the prediction models and at building a firm foundation for accomplishing the objectives of FGGE.

■ IMPACT OF THE DSTs

The impact of the DSTs on The Global Weather Experiment has been great. At least one system planned for FGGE was replaced after testing during the DSTs. Others, such as the AIDS and ASDAR concepts to obtain automated reports from aircraft, were shown to be extremely valuable, and are being expanded. Operational programs to obtain, communicate and process data have been improved as a result of DST experiences. The DSTs provided a basis for the design of data management procedures specifically tailored to The Global Weather Experiment. The difficulty of the data assimilation problem has been shown to be greater than anticipated and a variety of studies which will address the outstanding problem areas will be carried out prior to the start of FGGE. Most importantly, the DSTs provided a level of experience and knowledge essential to the successful operation of FGGE — The Global Weather Experiment.

The Department of Commerce operates two Command and Data Acquisition Stations to control the Operational Environmental Satellite System. Gilmore Creek, Alaska, and Wallops Island, Virginia, (shown here), control the position, orientation and data flow for both polar orbiting and geostationary satellites. From these two stations data are sent to a variety of users including the World Meteorological Center at Suitland, Maryland, where data of international significance are placed on the Global Telecommunications System.

2. The World Weather Program Plan

The World Weather Program provides the mechanism among the nations of the world for integrating activities directed toward improved weather and hydrologic services and environmental quality. The goals of the World Weather Program focus on extending the range and scope of weather forecasts, understanding the basis of climate and climatic changes, assessing the consequences of man's activities on the global atmosphere, and examining the feasibility of large-scale weather modification. This section reports on the U.S. progress, in conjunction with other nations of the world, in implementing the major elements of the World Weather Program. These elements are the World Weather Watch (WWW) and the Global Atmospheric Research Program (GARP), both of which are supported by the System Design and Technological Development program.

■ WORLD WEATHER WATCH

The World Meteorological Organization, a specialized agency of the United Nations with 144 Members, coordinates the international planning and implementation of the World Weather Watch. The international World Weather Watch Plan is updated in four-year cycles to coincide with the WMO financial period and the meetings of the WMO Congress. In 1975, the Seventh WMO Congress approved the WWW Plan for the period 1976-1979. To assist in the implementation of the WWW, a Voluntary Assistance Program has been established which consists of contributions by Members in terms of equipment and services, training, and cash. Annually, the WMO Executive Committee Panel on VAP meets to consider and recommend projects to be circulated for possible support.

The World Weather Watch is designed as an integrated global system consisting of observing, telecommunications, and data processing functions called, respectively, the Global Observing System (GOS), and Global Telecommunication System (GTS), and the Global Data Processing System (GDPS). Conceptually, it is convenient to think of the WWW as organized on a three-level basis, namely the global, the regional, and the national levels.

The Global Observing System consists of two subsystems that provide the meteorological and related environmental observations needed for the WWW and GARP. The first, the space-based satellite subsystem, is composed of polar-orbiting satellites and those in geostationary orbit. The second subsystem, the surface-based system, is composed of the basic synoptic surface and upper air networks, other stations on land and sea, and aircraft meteorological observations.

Rapid technological changes and exploding requirements for data from applied programs, particularly environmental monitoring, have led to important additions being included in the 1976-1979 Plan. Geostationary and polar-orbiting meteorological satellites are playing an ever increasing role. Automatic weather stations and especially buoys are becoming important sources of environmental information from data-sparse areas. Solid-state radars are being provided to stations in the tropics to obtain upper wind data.

The implementation of geophysical monitoring stations and the expansion of related observing programs have taken on an increased importance and are receiving special attention.

Satellite Observation ■

The United States operates a network of satellites and associated ground facilities to provide data used in meeting its responsibilities for meteorological prediction and warning, oceanographic and hydrologic services and space environment prediction and warning. In part, these responsibilities stem directly from commitments to the WWW. The evolving requirements of the satellite data users and the improved technology now available have led to the initiation of a third generation polar-orbiting satellite series. TIROS-N/NOAA, with its first launch planned for 1978, has been designed to provide better data than the present polar satellites. Its major data improvements will be higher accuracy and an increase in the number of atmospheric temperature and water vapor soundings, increased spectral radiometric information for more accurate sea surface temperature mapping and delineation of melting snow and ice fields, a remote platform location and data collection capability, and increased proton, electron, and alpha particle spectral information for improved solar disturbance prediction.

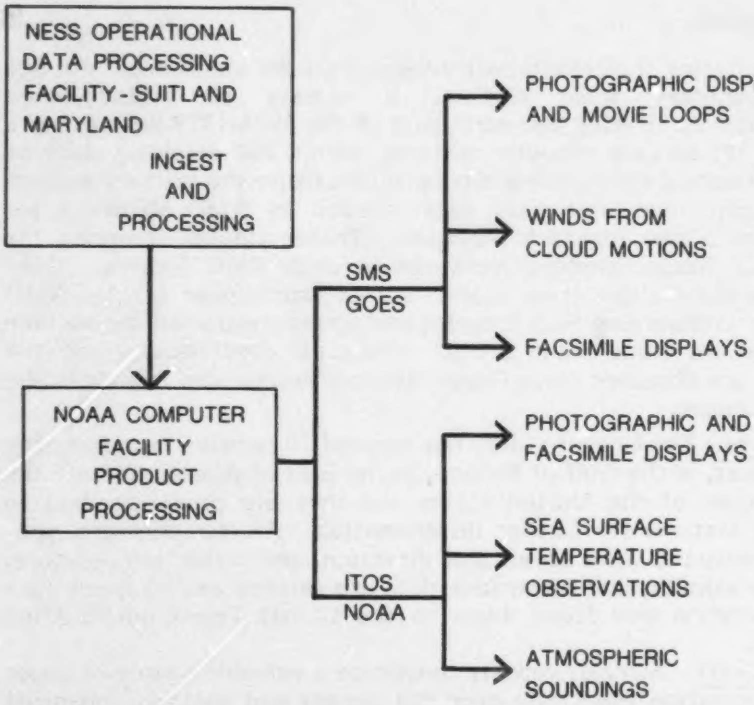
TIROS-N is a NASA and NOAA cooperative program. NASA funds the development and launch of the first flight hardware and procures and launches subsequent space hardware on a reimbursable basis. NOAA funds subsequent flight hardware, establishes the ground facilities, and operates the satellites in orbit.

Each polar-orbiting satellite operated by the United States is capable of daily providing two global sets of observations of cloud cover, vertical temperature and humidity profiles, sea-surface and land temperatures, and snow and ice cover.

Many of these data are inputs to numerical models for global analysis and prediction of weather systems. Data are received at Wallops Island, Virginia; and Gilmore Creek, Alaska; and then distributed by facsimile to National Weather Service forecast offices. Both the United States and the U.S.S.R. operate polar-orbiting satellites as part of the WWW.

The United States initiated the first stage of an operational geostationary satellite system with the successful launchings of the Synchronous Meteorological Satellites, SMS 1 in May 1974, SMS 2 in February 1975, and the Geostationary Operational Environmental Satellite (GOES-1) in October 1975. In June 1977, GOES-2 was launched and stationed over the equator at 75 degrees west longitude to replace GOES-1. Both SMS-1 and GOES-1 have been put on a reserve status due to the partial failure of some on-board

OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM


NESS OPERATIONAL DATA PROCESSING FACILITY - SUITLAND MARYLAND
INGEST AND PROCESSING
NOAA COMPUTER FACILITY PRODUCT PROCESSING
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NOAA
PHOTOGRAPHIC DISPLAYS AND MOVIE LOOPS
WINDS FROM CLOUD MOTIONS
FACSIMILE DISPLAYS
PHOTOGRAPHIC AND FACSIMILE DISPLAYS
SEA SURFACE TEMPERATURE OBSERVATIONS
ATMOSPHERIC SOUNDINGS

The Operational Enviornmental Satellite System consists of geostationary (GOES and SMS) and polar orbiting (ITOS and NOAA) satellites, and the facilities needed to support them.

systems. GOES-2 and SMS-2, at 135 degrees west, comprise the current operational geostationary satellite system. Launchings of three additional geostationary satellites are planned by the European Space Agency (ESA) and the Japanese and U.S.S.R. Governments between late 1977 and the end of 1978. Geostationary satellites monitor solar radiation, provide nearly continuous imaging of cloud cover and wind fields derived from cloud motions, and are relay points for data collection and distribution. Currently, 55 National Weather Service forecast offices and forecast centers receive SMS and GOES.

While the United States now relies heavily on the GOES, much of the world will continue to rely on polar-orbiting satellites for local satellite imagery until ESA, the U.S.S.R., and Japan launch their geostationary satellites. Local readout of cloud image data is still available from U.S. polar-orbiting satellites through the Automatic Picture Transmission (APT) service to all meteorological services able to make the modest investment in satellite radio receiving and display equipment. APT provides instant weather information, both day and night, over thousands of square miles in the vicinity of the local readout stations. Over 800 APT stations are operated worldwide in 130 nations.

Surface-Based Observations

Monitoring the global environment from the storm scale through the planetary scale requires a variety of surface-based observations. During the early part of the 1976-1979 period, more than 3,500 surface synoptic stations, about 700 sounding stations, and 100 optical wind-finding sites will constitute the primary sources of synoptic meteorological data needed by WMO Members for operational and research purposes. These stations comprise the Regional Basic Synoptic Networks in each WMO Region. Over 6,000 mobile ships from many nations participate in the WMO Voluntary Observing Ship program and furnish nearly all the surface observations from ocean areas. Upper air observations over the oceans are obtained from Ocean Station Vessels and islands in the major oceans.

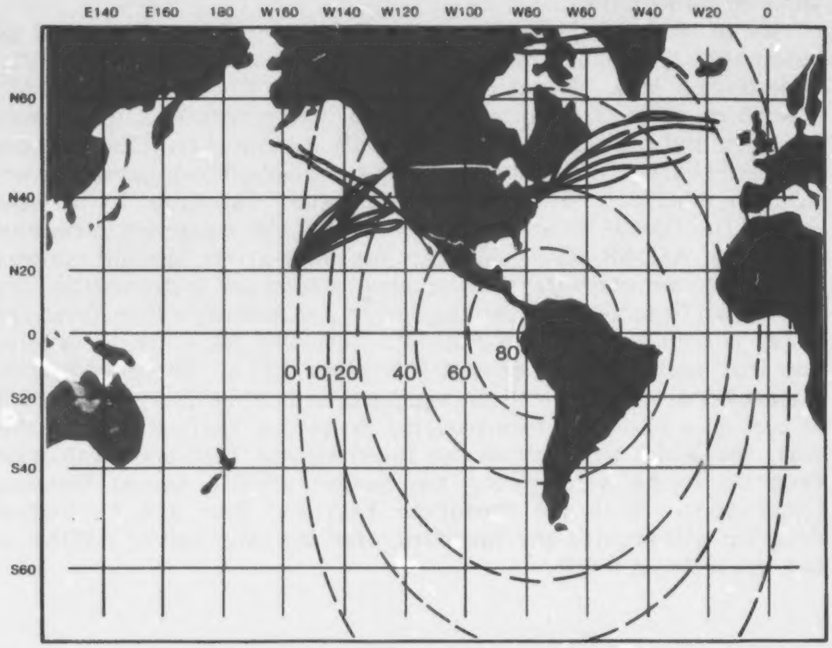
Buoys. The United States has moored 10 network buoys off the east coast, in the Gulf of Mexico, in the Gulf of Alaska, and off the west coast of the United States and they are providing data to coastal stations for further dissemination. Air temperature, sea-level pressure, wind speed and direction, sea-water temperature, surface salinity, and subsurface data are relayed each 3 hours to a shore station and from there to the Global Telecommunication System.

Aircraft. Aircraft reports constitute a valuable source of upper air information especially over the oceans and sparsely inhabited areas. Weather reports from commercial aircraft, made and reported internationally in accordance with procedures established by the International Civil Aviation Organization (ICAO) for enroute flight advisory service, are also used for providing current flight weather information.

NASA and the Department of Commerce have developed an automated system for obtaining aircraft reports from commercial wide-bodied jets. The Aircraft to Satellite Data Relay (ASDAR) assembles data on flight level wind, temperature and pressure altitude, and position from the aircraft instruments. Observations are taken each 7 1/2 minutes, stored and relayed to a geostationary satellite hourly. All of the geostationary satellites to be used during The Global Weather Experiment will be equipped to receive and relay ASDAR data. Reports received at the ground stations are sent to meteorological processing centers for transmission over the Global Telecommunications System. Currently a Pan American B-747 is equipped with an ASDAR. SAS and KLM are to receive one unit each in October and November 1977. Three additional international carriers will be equipped with ASDAR by April 1978 as part of a 12-month International Prototype Test. Following this test, the WMO will sponsor an International Test and evaluation Program to be held during the period of The Global Weather Experiment. Both the Prototype Test and Test and Evaluation Program will provide the foundation for the later use of ASDAR in the operational WWW.

The TIROS Meteorological Drifter (TMD) buoy provides a means of observing physical phenomena of the marine environment from remote locations. These platforms may free-float or be tethered relaying their observations through satellites (TIROS-N) to scientific processing and analysis centers.

FEBRUARY 1977 ASDAR DATA FLIGHTS
WITH CONTOURS OF CONSTANT ELEVATION TO THE RECEIVE SATELLITE



Shown are tracks of flights made by a Pan-American B-747 equipped with an ASDAR during part of February 1977. Meteorological data were received at each 7 1/2 minutes along these routes after being relayed from the aircraft through the GOES satellite.

In support of tropical cyclone and coastal storm forecasting, the Department of Defense conducts reconnaissance flights over Northern Hemisphere waters where tropical storms exist or are suspected. Weather observations are collected at flight level, and instruments are dropped from the aircraft to make measurements from flight altitude to the surface of the earth. The Department of Commerce, which performs tropical storm reconnaissance primarily in support of research and development programs, provides backup for hurricane reconnaissance aircraft in the Atlantic and Caribbean.

Automatic Weather Stations. The need for more surface data to support hydrologic, marine, aviation, and agricultural forecast programs and for climate and pollution monitoring has intensified the effort to develop and use automatic meteorological and hydrologic observing stations. Present devices use the latest advances in solid-state electronics, mini- and micro-computers for data processing. Some use solar cells to charge batteries; and most report data over telephone lines, by radio, or through geostationary satellites while the rest store data internally for later manual retrieval. Approximately 100 Automatic Meteorological Observing Stations (AMOS) of varying degrees of complexity have been installed by the National Weather Service, providing a basic set of data including air temperature, dew point, wind, pressure, and rainfall amount. Locations include remote coastal sites such as automated lighthouses, airports, and remote mountain passes. Automatic Hydrologic Observing Stations (AHOS) have been developed to report precipitation and river flow for hydrologic forecasting.

While most of the automatic stations support national programs primarily, others provide data exchanged bilaterally or internationally over the GTS as part of the WWW. The most important facet for the WWW, however, is that they all provide data needed to establish a baseline for worldwide geophysical monitoring and climate studies. In the next few years automatic stations will be considered and implemented as necessary for regional programs in support of severe storm forecasting.

Global Baseline and Regional Monitoring

One aim of the World Weather Program is to extend and improve the measurements of the atmospheric constituents to permit an assessment of the global impact of man-made and

Health and Safety Laboratory precipitation and dry deposition samplers, located at the Energy Research and Development Administration's site in Chester, New Jersey. Data from these sites will be used to determine long term trends of anthropogenic pollution in precipitation and dry deposition.

natural constituents on climate. Global monitoring consists of both baseline and regional stations.

Solar Radiation. In CY 1977, the U.S. program to measure solar radiation was revitalized to provide a larger data base for both global climate studies and engineering design. The Department of Commerce installed 35 pyronometers to measure whole sky radiation. In FY 1978, 35 pyrheliometers will be installed to measure the sun's direct radiation.

Baseline Monitoring. The baseline stations are located in remote areas with long air trajectories passing over uniform surfaces to minimize both natural and man-made pollutants. The U.S. baseline program, a part of the WMO network, is conducted at four observatories: Mauna Loa; American Samoa; Barrow, Alaska; and at the U.S. South Pole Station. The measurements at baseline stations are comprehensive and include the principal trace constituents important for climate studies: Carbon dioxide, ozone, fluorocarbons, and aerosol particles.

Mauna Loa is the oldest of the four observatories and has the largest number of measurement programs. It is also the highest observatory at 3400 meters (11,150 feet) and samples tropospheric background air, unaffected by island sources, about half of each day. An enhanced precipitation chemistry program will be conducted in FY 1978.

The observatory at American Samoa was completed in 1975 and the full-scale measurement program began in early 1976. The University of Rhode Island is conducting a cooperative program at the observatory site.

At Barrow, Alaska, a full-scale program continues at the baseline observatory a few kilometers northeast of the Naval Arctic Research Laboratory. A LIDAR program will begin in FY 1978.

The temporary, under-snow facilities which housed the baseline observatory at the U.S. South Pole Station, were abandoned in early 1977. The observatory was relocated in a new building constructed by the National Science Foundation during the austral summer of 1976-77. A complete measurement program is continuing at the South Pole Observatory.

Regional Monitoring. Stations in the United States designated for regional monitoring concentrate on measurements of man-made atmospheric constituents originating within the national boundaries of the contiguous United States. The measurements at these stations will be useful in documenting the levels of atmospheric constituents crossing national boundaries for application to future problems in international law, as well as for scientific applications.

Some U.S. regional stations measure atmospheric turbidity and collect precipitation for chemical analysis. The turbidity measurements allow monitoring of a potential increase in aerosols over the United States, and the analysis of precipitation samples provides information on the acidity of rainfall, which is increasing over the eastern United States.

Other U.S. regional stations measure the total amount of ozone in the atmosphere above the station as part of a program to determine long term ozone trends over the United States. These stations are part of a WMO global ozone network.

The Energy Research and Development Administration (ERDA) operates a network of 125 land stations to measure, on a monthly basis, the fallout rate of important radionuclides. Data are used to study the global fallout rate and to assess the fallout inventory. Weekly surface air samples are collected at about 20 stations at latitudes ranging from 77°N to 90°S along the 80th meridian to provide data on the latitudinal distribution of radionuclide debris.

Deposition of a number of non-nuclear energy-related pollutants is being studied by ERDA in the New York City area and at Woods Hole, Massachusetts, on the east coast; in San Francisco, California and Seattle, Washington, on the west coast; and near Chicago, Illinois, in the midwest. These studies have been extended by installing instruments at NOAA's baseline stations at Mauna Loa and American Samoa.

Additionally, four sites have been instrumented to measure acid precipitation as part of the Multistate Atmospheric Power Production Pollution Study (MAP3S). These sites are at: Whiteface Mountain, New York; Ithaca, New York; State College, Pennsylvania; and Charlottesville, Virginia.

■ Global Data Processing System

The Global Data Processing System of the international WWW Plan is designed to make available to the meteorological services of the world processed data and products required for preparing forecasts and warnings and for climatological and research purposes. Data are available on a real-time and a non-real-time basis. Adjustments were made in the WWW Plan for 1976-1979 as a result of new developments, including more efficient and sophisticated processing techniques, the availability of more powerful computers, better coordination of the real-time and delayed functions of the processing centers, and emphasis on the four-dimensional data assimilation techniques, particularly vertical nations of WMO through the GTS.

In the United States, the WMC consists of three components: the National Meteorological Center at Camp Springs, Maryland; the National Climatic Center at Asheville, North Carolina; and part of the National Environmental Satellite Service at Suitland, Maryland. Historically, numerical models have used data from fixed or synoptic times; however, with the technological changes brought about by satellite observations, meteorological data are now available on a nearly continuous basis. An analysis scheme still being improved, but used routinely, assimilates into the data base observations taken at any time. A fourth-generation computer was an important advance at the WMC that made such data assimilation possible. This computer is also used to process both day and night images from GOES and to run complex, multi-layered hemispheric and global models.

Regional Meteorological Centers

There are 23 Regional Meteorological Centers (RMC) worldwide with limited meteorological analysis, processing, and forecasting capabilities. The United States operates an RMC at Miami which provides regional analyses and predictions for the Caribbean, Central America, Northern South America, and adjacent tropical ocean areas. It is operated in conjunction with the Regional Center for Tropical Meteorology in support of the U.S. hurricane forecasting office. The Center has developed a series of statistical hurricane prediction models aimed at increasing the capability of the Center to more accurately predict landfall and reduce the 24-hour forecast position error. WMC Washington has developed a multi-level, fine-mesh hurricane model for operational use at the Regional Meteorological Center at Miami. In addition to hurricane and tropical storm advisories, the RMC, Miami, provides, on request, marine and aviation weather forecasting services to foreign countries in its area of responsibility.

National Meteorological Centers

The National Meteorological Centers (NMC) are designated under the international WWW Plan to satisfy the data processing needs on the national level, assisted as required by the output products of WMCs and RMCs. As on the global and regional levels, the NMCs have both real-time and non-real-time functions. At the national level many of the NMCs provide direct support to the users of meteorological services.

Global Telecommunication System

The Global Telecommunication System (GTS) consists of telecommunication facilities and arrangements necessary for the rapid collection and distribution of basic observational data and processed information. It is organized on a three-level basis:

The Main Trunk Circuit (MTC) and its branches
The Regional Telecommunication Networks
The National Telecommunication Networks

The GTS plan for 1976-1979 includes increased use of computer-to-computer techniques, high-speed data exchange, and the introduction of coded digital facsimile techniques on the MTC. These techniques will permit increased global exchange of satellite data and computer-derived products.

The Main Trunk Circuit is a high-capacity telecommunications link interconnecting all WMO regions through three World Meteorological Centers and eight Regional Telecommunication Hubs (RTH). Three additional RTHs are situated on branches of the

Main Trunk Circuit, one of which was added recently at Peking. The Global Telecommunication System has been designed to handle the expected traffic for the WWW. It is anticipated that the additional traffic generated during FGGE — The Global Weather Experiment, in particular the data desired for use in real-time, will be accommodated on the GTS as will real-time data needed by EARTHWATCH and Integrated Global Ocean Station System (IGOSS). Four critical parts of the MTC have a capacity of 2400 bits per second and are capable of handling large amounts of data. The RTH Washington to RTH Tokyo circuit operates over a cable at 2400 bits per second and plans are to add a fascimile channel in early FY 1978. The link from Washington to RTH London also operates at 2400 bits per second and the fascimile channel is in operation. Because of the very large amount of data expected to be available from satellites, demands of other UN programs, and stringent time limits set for the transmission of data on the MTC, even higher data signaling rates (e.g., 4800 bits per second) are needed. Further development and improvement of the GTS to provide these higher transmission rates are tasks to be undertaken during the period 1976-1979.

■ Regional Telecommunications Networks

Regional telecommunication networks provide for the rapid collection of observational data at the Regional Telecommunications Hubs (RTH), particularly those that connect regional circuits with the MTC. The regional telecommunication networks also provide for the distribution of observations and processed information to NMCs and thus insure that all Members of WMO receive the data they require.

The United States operates a number of international regional circuits in cooperation with other countries in its region. For example, a high-speed circuit connects Washington and Toronto, while low-speed circuits are installed between Washington and Mexico City, and between Washington and Nassau. Low-speed circuits also connect Washington with the capitals of the Central American republics and with many of the islands in the Antilles. The United States also operates three radioteletypewriter broadcasts and two radiofacsimile broadcasts within the region.

■ National Telecommunications Networks

The Department of Commerce has begun procurement of equipment for the National Weather Service's program called Automation of Field Operations and Services (AFOS). After several years of development and evaluation, phase one of the AFOS system is now being installed at NWS Headquarters in Silver Spring, Maryland, for final evaluation. Field implementation is due to begin in late FY 1978. At the "heart" of each station are minicomputers designed to exchange information between forecast offices at 2400 to 4800 bits per second. Meteorologists at each forecast office can view data and weather maps on television-type displays driven by the on-site mini-computers. Data will be more readily available to the meteorologist and he can prepare his forecasts more quickly. AFOS will allow him to be better informed and to keep up with rapidly changing events. In addition to changes at the forecast office and in the telecommunications network, AFOS will allow the direct input of digital data from observing systems such as automatic weather stations, semi-automated upper air sites and storm detection radars equipped with mini-computers.

Voluntary Assistance Program

The implementation and development of, and benefits to be realized from the WWW are dependent upon the participation of all the meteorological services of the world. Some developing countries do not have the resources or the technical and scientific knowledge to participate freely in the World Weather Program. Technical and financial assistance provided to these countries results in both an improvement of their meteorological and hydrologic programs and a more vigorous international effort. Assistance may be provided in part by:

The United Nations Development Program
Bilateral or multi-national agreements
Contributions in financial form or in the form of equipment or services by Members of the WMO. These latter contributions constitute the WMO Voluntary Assistance Program (VAP). The history of VAP is shown in the accompanying figure.

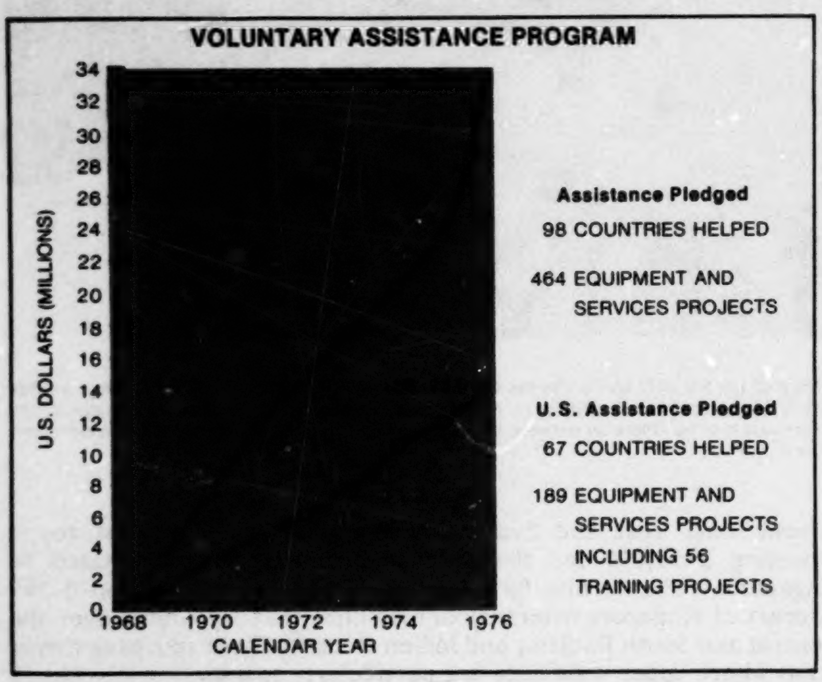
The Voluntary Assistance Program is a major form of assistance in helping developing countries to implement and benefit from the WWW by providing equipment, expert services, and long-term fellowships. The priority for support includes elimination of major deficiencies in the observing functions, in the capabilities of the telecommunications system to move data globally, and in qualified personnel to make use of the meteorological data made available through the WWW. Support through VAP has been provided in Africa, South and Central America, and Asia to improve the availability of upper air data from these locations. Deficiencies still exist in tropical areas and these will be addressed during the 1976-1979 period. As a result of VAP all the RTHs on the MTC and its branches have been implemented. Except for a few facilities the RTHs on the regional meteorological circuits have also been or are in the process of being implemented. Point-to-point and national observational collection networks are expected to be fully supported by the end of 1979.

During CY 1976, the ninth year of operation, eighteen Members of the WMO contributed $210,000 to the VAP cash fund; the United States contributed $137,000. Since 1968, 50 Members have contributed $3,500,000 to the cash fund. Also during CY 1976, 23

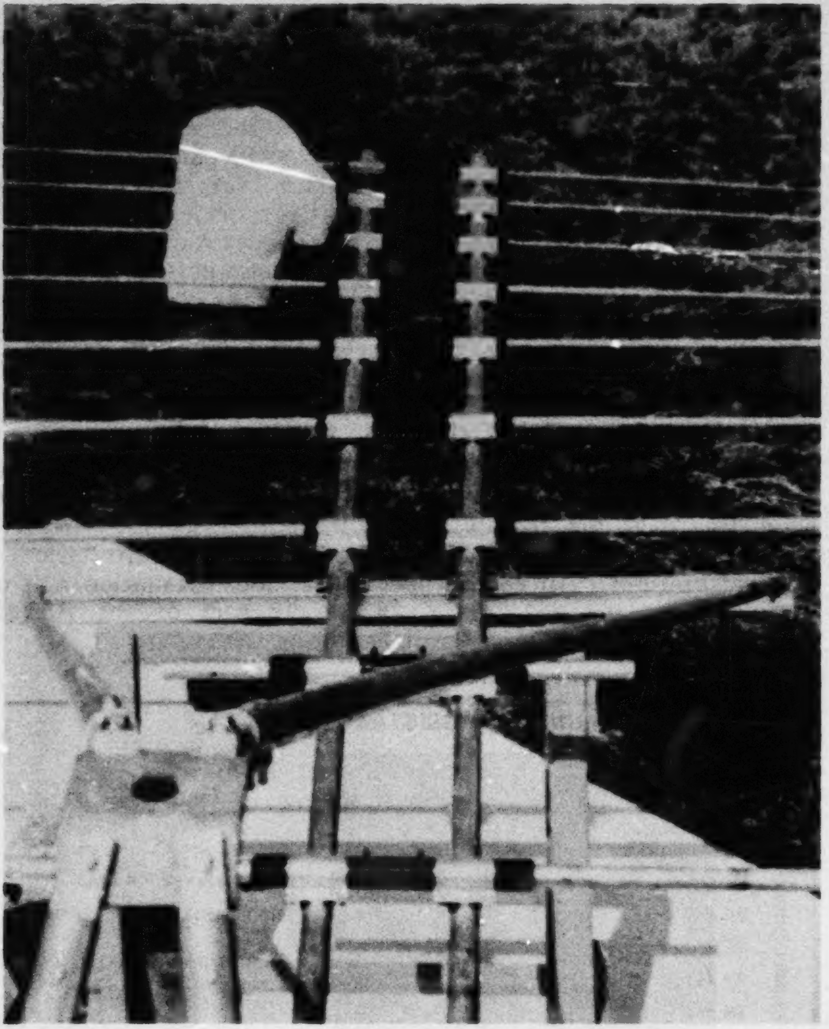
Members contributed $3,400,000 in equipment, services and training. The U.S. contribution was $1,850,000. Approximately $29,900,000 has been provided since 1968 for equipment, services and training. An additional $2,900,000 has been contributed by Members through bilateral programs toward the implementation of VAP programs. Therefore, the total VAP contributions (less bilateral arrangements) from CY 1968 to CY 1976 have been $33,400,000; of which the United States has provided $14,000,000.

Currently there are 135 VAP projects approved for circulation to potential donors. Of the 90 new projects, 41 are for improvements to the observing system, 17 for telecommunications, 3 for hydrology and 29 for training. Since its inception, 746 projects have been approved for circulation to Members for support.

For the CY 1977 programs (FY 1977 and some FY 1978 funds), the United States is placing a major emphasis on improving observing and telecommunications programs for The Global Weather Experiment. The highest priority is to obtain upper level wind data over the tropics and Southern Hemisphere. Thirteen wind finding radar systems are being purchased for installation at tropical stations. Three are operational and installation will be completed by the end of CY 1978. As part of the ASDAR



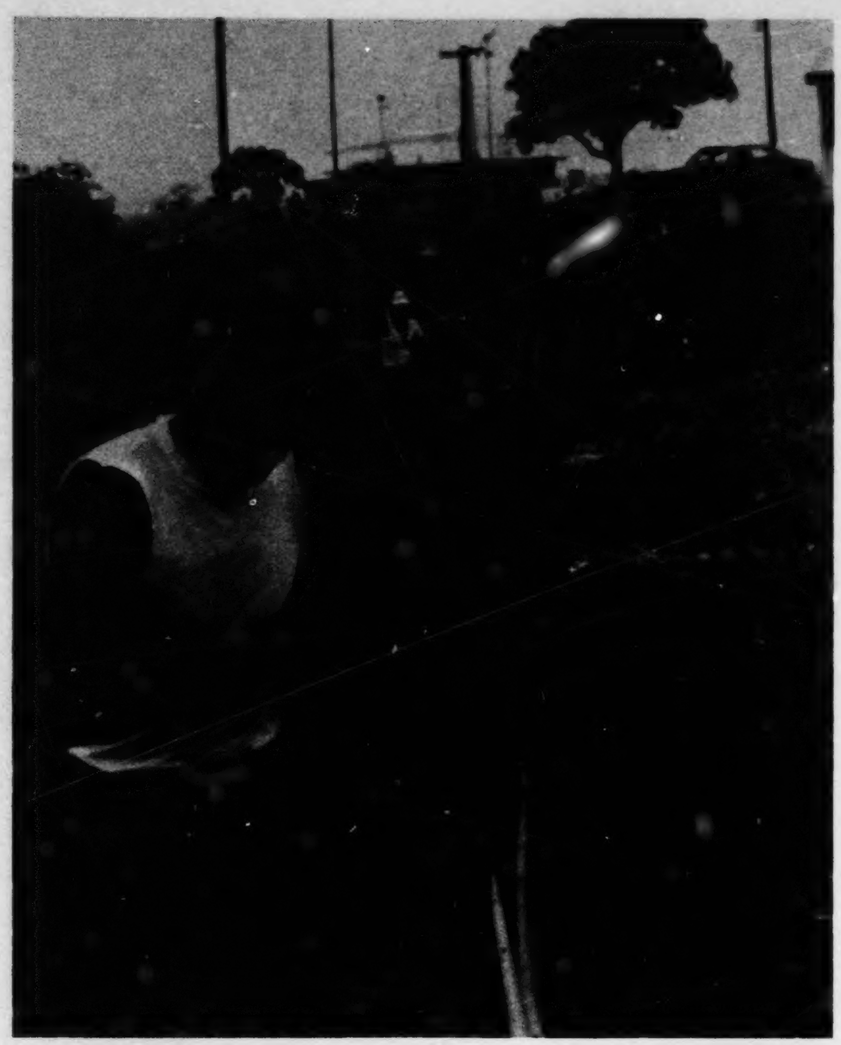
Contributions to the WMO Voluntary Assistance Program by the United States and other nations through 1976.



Part of the FY 1977 United States Contribution to the Voluntary Assistance Program was to improve national facilities to receive processed information including analysis and forecast charts. Here an antenna to receive radio facsimile is assembled in Panama by a local worker.

International Test and Evaluation Program, the United States is providing $150,000 for the purchase of units to be donated to Singapore. These units (probably five) will be installed on B-747 aircraft of Singapore International Airlines that fly routes over the Central and South Pacific, and Indian Ocean. These routes are over areas where upper wind data are particularly sparse.

One critical item receiving increased emphasis is to improve the exchange of data over the Global Telecommunications System.



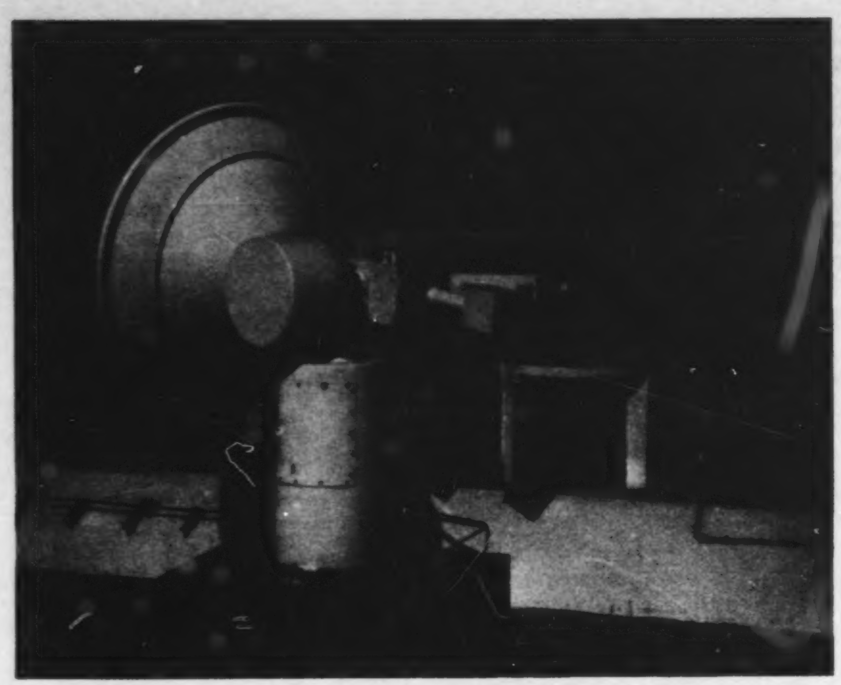
Contributions made by the United States to Members of the World Meteorological Organization through the Voluntary Assistance Program are matched by their recipient, usually through the cost of constructing facilities. Here cables are led from the office to the antenna as part of the radio facsimile installation in Panama.

As the GTS becomes increasingly reliant on automatic switching, the accuracy and timelines of the data reports assume new significance. At an Extraordinary Session of the Commission for Basic Systems in 1976, a plan was adopted for monitoring the operation of the World Weather Watch. Integral to that plan is the need to monitor the exchange of data on the GTS. The United States will implement a monitoring program for data exchanged between the WMC Washington and Members in the Western

The first three of thirteen small radars to obtain information on upper air winds have been installed. Built by a U.S. firm and provided through the Voluntary Assistance Program, these radars are both easier and less expensive to operate than previous systems. Operators and technicians, such as the person shown at the Nouadibou, Mauritania, station, are trained in the United States through the Voluntary Assistance Program short term fellowship program.

Hemisphere. A pilot project has begun between WMC Washington and the Regional Telecommunications Hub at Brazilia.

To further assist WMO Members to improve the quality and reliability of their observing programs, the United States, using VAP funds, has placed on assignment a technician who is an expert in electronics and communications. His role is to provide assistance to WMO Members in Central and South America in the



The installation of a new wind-finding radar station at Nouadibou, Mauritania. Data from these newly established stations are important to global analyses because they help to fill gaps in the coverge over the tropics.

installation and maintenance of observing and telecommunications equipment. In addition, the United States has conducted short term training programs at the NOAA training facility in Kansas City.

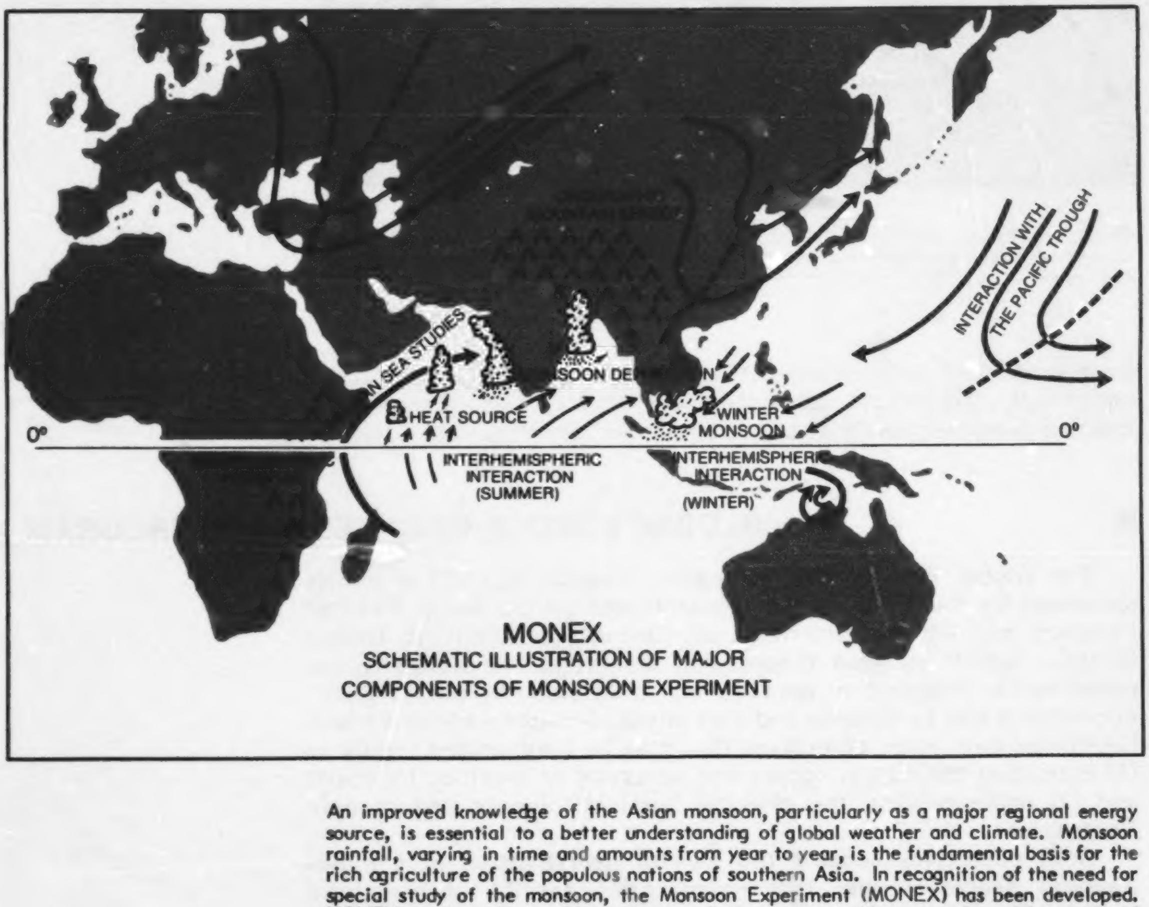
■ GLOBAL ATMOSPHERIC RESEARCH PROGRAM

The Global Atmospheric Research Program (GARP) is jointly sponsored by the WMO as the research part of the World Weather Program and by the International Council of Scientific Unions (ICSU). GARP includes theoretical, numerical and observational experiments designed to improve our understanding of the global atmosphere and to develop and test physical-mathematical models. GARP has two major objectives that may be summarized briefly as (1) extending the range, scope, and accuracy of weather forecasts and (2) understanding the physical basis of climate and climate fluctuations.

Both objectives require the careful investigation of complex physical processes and the mounting of special observational experiments required to formulate and test theories and models. Some processes can be studied through regional experiments.

Examples are the GARP Atlantic Tropical Experiment (GATE), which emphasized the role of convective tropical systems on the global circulation; the Air Mass Transformation Experiment (AMTEX), which concentrates on the processes of intensive transformations of air moving from cold land over strongly contrasting warmer water; the Monsoon Experiment (MONEX), which studies the mechanics of the Monsoon circulation; and the Polar Experiment (POLEX), which examines the role of polar regions in global energetics.

The second GARP objective, climate, leads inevitably to consideration of the role of the oceans and the development of coupled ocean-atmosphere models. The following sections present some highlights of current GARP activities.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MONEX
SCHEMATIC ILLUSTRATION OF MAJOR
COMPONENTS OF MONSOON EXPERIMENT

An improved knowledge of the Asian monsoon, particularly as a major regional energy source, is essential to a better understanding of global weather and climate. Monsoon rainfall, varying in time and amounts from year to year, is the fundamental basis for the rich agriculture of the populous nations of southern Asia. In recognition of the need for special study of the monsoon, the Monsoon Experiment (MONEX) has been developed. MONEX consists of a coordinated group of observational efforts, together with associated data processing and research programs, over the Indian Ocean, Arabian Sea, Bay of Bengal, southeast Asia, and South China Sea.

GARP Atlantic Tropical Experiment

The GARP Atlantic Tropical Experiment (GATE) was designed with two central objectives:

1) Provide a means of estimating the effects of smaller scale tropical weather systems on the larger scale (synoptic-scale) circulations,
2) Facilitate the development of numerical modeling and prediction methods.

GATE conducted a highly successful field observation phase during the summer of 1974. Scientific, technical, and support personnel from 69 nations merged their efforts into a concentrated and coordinated investigation of the behavior of, and interactions between, the tropical atmosphere and oceans. As shown in the accompanying figure, the broad area of the experiment includes the entire tropical Atlantic Ocean and adjacent continental regions, the Caribbean Sea and smaller segments of the Gulf of Mexico, the eastern Pacific and the western Indian Ocean. A selected smaller area, a hexagon 90 nautical miles on a side centered at 8.5°N, 23.5°W known as the B-scale was the subject of intensive observations by ships and aircraft. Data were also collected throughout the GATE area by buoys, sun-synchronous and geostationary satellites, and the World Weather Watch network of continental and island-based weather stations.

One thesis is that convective systems, besides being a dominant feature of the weather in the tropics, provide a driving force for the atmosphere by transporting vast quantities of heat and moisture from the tropical oceans into the atmosphere at higher latitudes. Therefore, middle latitude weather is affected by tropical convective activity. These systems are coupled to the processes and circulation features of the oceans; consequently, oceanographic studies are an important part of the experiment.

The knowledge and experience derived from GATE is providing a basis for a significant advance in the understanding of tropical meteorology and for the development of weather forecasting in the tropical belt. The processes under study are also fundamental to the initiation, development, and maintenance of intense tropical storms and hurricanes that menace populated areas surrounding the tropical oceans. Improvements in the physical formulation of tropical processes in large-scale mathematical models of the global atmosphere are required to permit significant extensions in the range and quality of forecasts at any location and to gain a better understanding of climate and climatic change.

Data Management

The GATE data are being processed according to guidelines documented in the GATE International Data Management Plan. A major portion of the data processing effort, which commenced shortly after the completion of field activities, has now been completed. About 95% of the data has been processed at the national level by National Processing Centers (NPCs).

Immediately on completion of processing and validation procedures, the NPCs forward data to identical GATE archives at World Data Centers (WDCs) A and B in the United States and the Soviet Union, respectively.

As soon as the data are received at the WDCs, they are made available to the scientific community. In addition to forwarding the data to the WDCs, NPCs simultaneously send certain previously specified subsets of the data to Sub-program Data Centers (SDCs). Specialized data processing activities at the SDCs are tailored to meet requirements in particular scientific areas of investigation.

Original plans called for the SDCs to have completed their work by March 1977. However, some delays have been encountered. It is now expected that SDC work will continue through CY 1977.

GATE Research Program

The international GATE research program is proceeding with increasing scope and intensity as more and more data become available to the researchers. Initial assessments are quite optimistic that the quantity and characteristics of the data collected and the quality of the processed data set are adequate to permit the accomplishment of GATE's principal scientific objectives.

Within the U.S. scientific community, the GATE research effort is relatively evenly distributed between federal and non-federal research centers. Approximately 140 principal scientists at 42 institutions have been funded to work on specific GATE problems, including significant in-house GATE efforts at several government research centers.

A major task within the framework of GATE involves the synthesis of the results of these research programs into a comprehensive report dealing with the central objectives of the experiment. Detailed planning for preparing the report is currently underway in the United States. A major seminar was held during the summer of 1977 to develop the content of the report. Similar international activities will probably take place during 1978 and 1979.

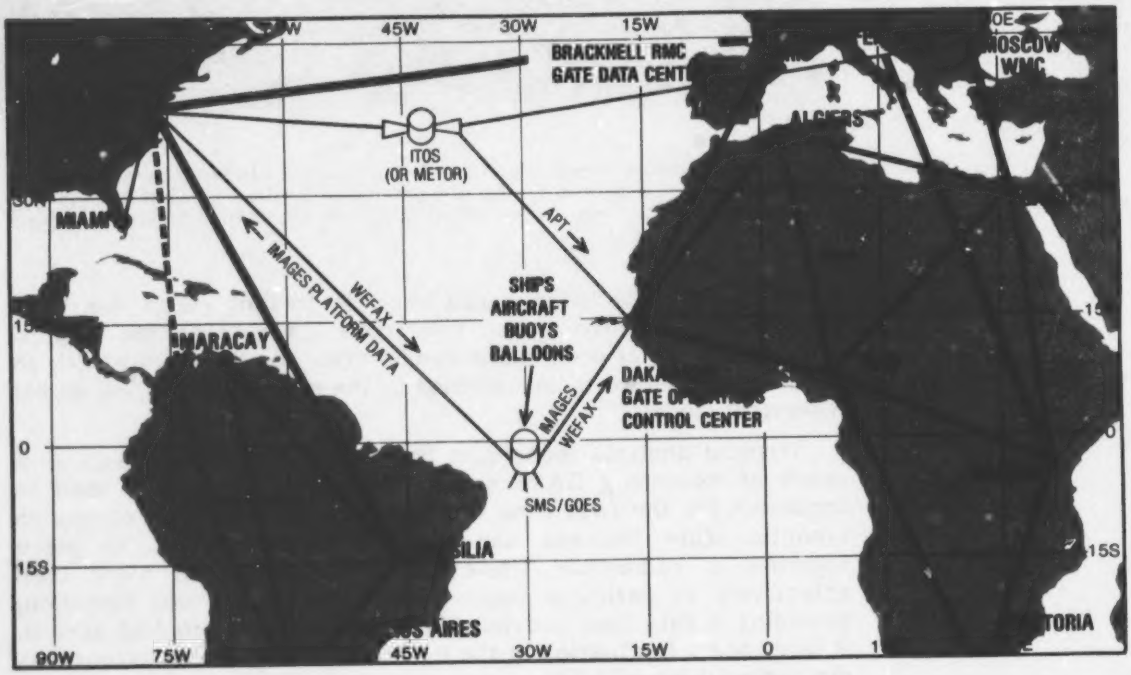
Through mechanisms such as international workshops, symposia, and scientific exchange visits, coordinated through the World Meteorological Organization in Geneva, the various national GATE research efforts are kept abreast of developments by foreign colleagues.

Localized lines of rainshowers, or squall lines, over West Africa have been linked to easterly waves. Easterly waves are disturbances in the trade winds and move from east to west through the Northern Hemisphere subtropics. Squall lines have been noted to form in preferred areas of the easterly waves. If supported by further analysis, this knowledge could have particular significance for forecasting precipitation over West Africa.

Direct and substantial evidence has been obtained on how air immediately below clouds interacts with the cloud layer to modify and modulate the cloud fields of larger scale systems. This information is fundamental to estimating the energy transport by smaller-scale features and to predicting the growth and decay of tropical cyclones. Scientists using GATE data have successfully developed for the first time a numerical model of vertical transports of heat, moisture, and mass in the undisturbed tropical

GATE DATA FLOW

GLOBAL TELECOMMUNICATION SYSTEM


45W
30W
15W
BRACKNELL RMC
GATE DATA CENT
MOSCOW
WMC
ALGIERS
ITOS
(OR METOR)
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APT
IMAGES PLATFORM DATA
WEFAX
SHIPS
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BUOYS
BALLOONS
MARACAY
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CONTROL CENTER
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WEFAX
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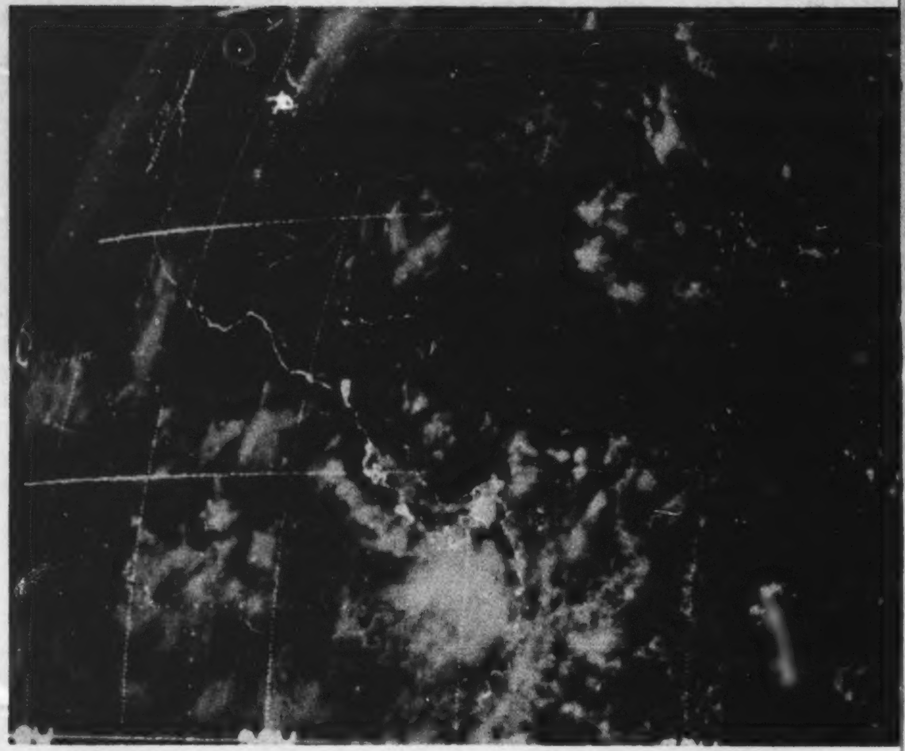
The GATE provided both valuable experience in conducting large scale environmental experiments and served to demonstrate ways to improve the operations of the World Weather Watch. Communications used during GATE included World Weather Watch facilities and special links such as relaying data to satellites from remote platforms.



An Easterly Wave, a potential hurricane in the making, is located between 10 and 20 degrees North latitude and 40 and 50 degrees West longitude at 1230 P.M. EST, on September 17, 1976. Over the tropical Atlantic, these storms from Africa move toward

boundary layer including radiation. A further result has been growing evidence that given good data coverage in the tropics, numerical weather predictions can be made for the tropics with an accuracy similar to those obtained in the extratropics using global numerical models.

Tropical analysis techniques have been advanced greatly as a result of examining GATE data. These data have been used to document for the first time the structure and evolution of enough synoptic scale features and tropical cloud clusters to piece together a reasonable life-cycle. Satellite data were used effectively to estimate upper level wind speed and direction, providing a data base previously unavailable over tropical oceans. A large scale fluctuation in the equatorial ocean undercurrent was discovered during GATE.

A technique has been developed, software written, and initial quantitative results obtained for automated rainfall estimates using information from microwave sensors on a geosynchronous satellite.

the Americas and are noted as a disturbance, or wave, in the trade winds. Not all Easterly Waves develop into hurricanes, but tracking them using GOES and SMS images has greatly improved the capability to anticipate hurricane formation.

These data have been calibrated using quantitative information from ship radars.

■ Data Systems Test (DST)

As discussed in Chapter 1, the purpose of the Data Systems Tests (DST) is to serve as a precursor for the global experiment and provide a broad operational test of many of the proposed concepts, elements, and interfaces involved in FGGE -- The Global Weather Experiment. The basic approach has been to use current operational satellite and conventional meteorological data, along with data from research and development satellites, to approximate the elements of the proposed observation system for FGGE. NASA directs and manages the DST with the cooperation and participation of NOAA.

In FY 1977 NASA expanded the DST research efforts to enlist the services of the entire meteorological community by offering an Announcement of Opportunity to conduct basic research using the

DST global data sets. These studies, which will continue into FY 1978, include determining the adequacy of the observing system and the impact of its various components, evaluating and improving methods for deriving meteorological parameters from sensor data, developing improved methods for assimilating satellite data, and improving forecast models.

First GARP Global Experiment (FGGE)-The Global Weather Experiment ■

The vast majority of global meteorological observations originate from the Northern Hemisphere. Yet more complete and improved global observations are needed (1) to establish the starting point for global weather forecasts made using existing physical-mathematical models of the global atmosphere and (2) to test, verify, and improve the performance of existing forecasting and climate models. Only by comparison with actual observation can critical improvements be achieved.

Specifically the major objectives of FGGE -- The Global Weather Experiment are:

- To better understand atmospheric motion for the development and evaluation of more realistic models used in extended-range forecasting and studies of the general circulation and climate;
- To assess the ultimate limit of predictability of weather systems of various sizes and item scales;
- To develop more powerful methods for assimilating multi-source meteorological observations, particularly for using non-synchronous satellite data to determine the initial state of the atmosphere for predicting large-scale motions; and
- To design an optimum composite global observing system for the operational WWW.

In support of these objectives the most comprehensive observational program of the tropospheric and stratospheric portion of the atmosphere and the sea surface yet attempted will be initiated in December 1978 and last for one year. Two intensive observational or special observing periods will be conducted during January-February and May-June of 1979. To support this intensive phase of FGGE, a special observing system will be implemented. Special efforts will be made to observe the tropics and the Southern Hemisphere.

Observing Systems. The WWW through its observing, processing, and telecommunication systems in conjunction with two polar-orbiting meteorological satellite systems and five geostationary satellites spaced around the globe will constitute the Basic Observing System for the FGGE. A Special Observing System, consisting of aircraft releasing dropwindsondes, ships fitted with windfinding sondes, drifting buoys, constant level balloons, as well as supplementary surface stations, and commercial aircraft and ships equipped with meteorological instruments, will be specially implemented for FGGE. Research satellites, such as NIMBUS G and SEASAT A, if available, will augment the total FGGE observing system.

The next generation polar-orbiting satellite system (TIROS-N) is essential to FGGE because this satellite system will provide a global data collection and mobile platform location capability in addition to improved accuracy associated with atmospheric soundings. The geostationary satellites possess a global communications and a high resolution imaging capability. The latter capability will permit wind determination at several levels in the atmosphere over a significant portion of the Earth-based observations from WWW networks will be indispensable and will include new stations implemented in accordance with the international World Weather Watch Plan for 1976 - 1979, as well as WWW stations temporarily implemented during the special observing periods. Special importance is attached to twice-daily radiosonde/radiowind observations and the collection of data from commercial aircraft and ships.

Plans for developing an automated aircraft meteorological reporting system, a new element of the WWW, are progressing on schedule. High quality ASDAR data, particularly from data-sparse regions, will serve not only as additional observations for the FGGE, but also as calibration points for satellite remote -- sounder temperature profiles and winds deduced from sequential satellite cloud images. ASDAR systems automatically transmit digital information on position, temperature and wind at flight level to geosynchronous meteorological satellites for relay to ground stations. NASA and NOAA are cooperating in the continued development and testing of this system. The feasibility of the aircraft-satellite link has been demonstrated and prototype systems have been built by NASA. Two international test programs have been established, an International Prototype Test, which has begun and will conclude in August 1978 and an International Test and Evaluation Program scheduled to coincide with the FGGE operational period.

Special FGGE observing systems covering both the equatorial tropics and the Southern Hemisphere are needed to more completely describe the global state of the atmosphere. Theoretical studies and numerical experimentation have demonstrated a critical need for direct wind measurements with high vertical resolution in the equatorial zone (about 10°S to 10°N). In addition, reference-level data in the Southern Hemisphere are needed to complement temperature and moisture soundings from satellite radiance measurements. Aircraft coupled with specially instrumented ships constant level balloons, surface based stations of the WWW and satellite derived wind vectors, will help fill the gap in the equatorial zone. The Aircraft Dropwindsonde Program, the largest single U.S. contribution to the special observing systems for FGGE, will provide a significant portion of the direct observation of vertical profiles of the wind field required in the equatorial tropics. According to present plans, one flight per day would be flown along each of five or six tropical tracks; three in the Pacific Ocean region, two in the Indian Ocean and possibly one track in the Atlantic. The final aircraft track locations will be chosen to complement the radiowindsonde releasing Tropical Wind Observing Ships (TWOS), as the ships number and positions become more definite.

The Tropical Constant Level Balloon (TCLB) System for FGGE complements the Aircraft Dropwindsonde Program by providing winds and temperature above the aircraft flight levels in the zone 20°N to 30°S latitude. The TCLB system is being implemented by the National Center for Atmospheric Research with funding by NOAA and NASA. It is planned that a total of 300 balloons will be launched with ground data processing being provided by the French utilizing the TIROS-N/Argos satellite data collection and platform location system.

In addition, approximately a dozen nations are contributing towards a network of about 300 hundred drifting buoys, planned to provide at least surface pressure and sea-surface temperature data in the Southern Hemisphere. These special observing systems will be implemented specifically for FGGE and will be especially important during the two FGGE observing periods scheduled for January-February and May-June 1979.

NIMBUS G, a research satellite scheduled to be launched the first half of calendar year 1978 is of considerable value to FGGE planning because its infrared and microwave soundings will provide nearly complete global coverage. NIMBUS G sensors will provide information on the Earth's radiation balance, total ozone concentration, stratospheric temperature soundings, sea ice concentration, rainfall rate, water vapor concentration, wind speed, and sea-surface temperature for the FGGE data base. These measurements will improve present understanding of the liquid water contents of clouds over water, distribution and variation of sea-ice and moisture characteristics of land surfaces, while the Earth Radiation Budget experiment will provide data for investigating the earth's radiation balance, an essential part of climate studies. Additionally, the coastal zone color scanner will be used to identify variations in ocean water color and to quantify water content such as chlorophyll sediment and gelbstaffe.

NASA plans to make available to the FGGE archives certain data sets derived from the NIMBUS G and SEASAT A research satellites. SEASAT is the first satellite designed primarily to observe oceanic surface conditions. The plans for their use in FGGE are contingent upon the performance of the satellites themselves and the operation of the ground based systems as planned. Production of the products derived from the satellite data will be started during FY 1979.

Additional oceanographic and atmospheric observations during the FGGE are planned in connection with regional experiments, such as MONEX, POLEX, and WAMEX, also in support of national and international climate program objectives.

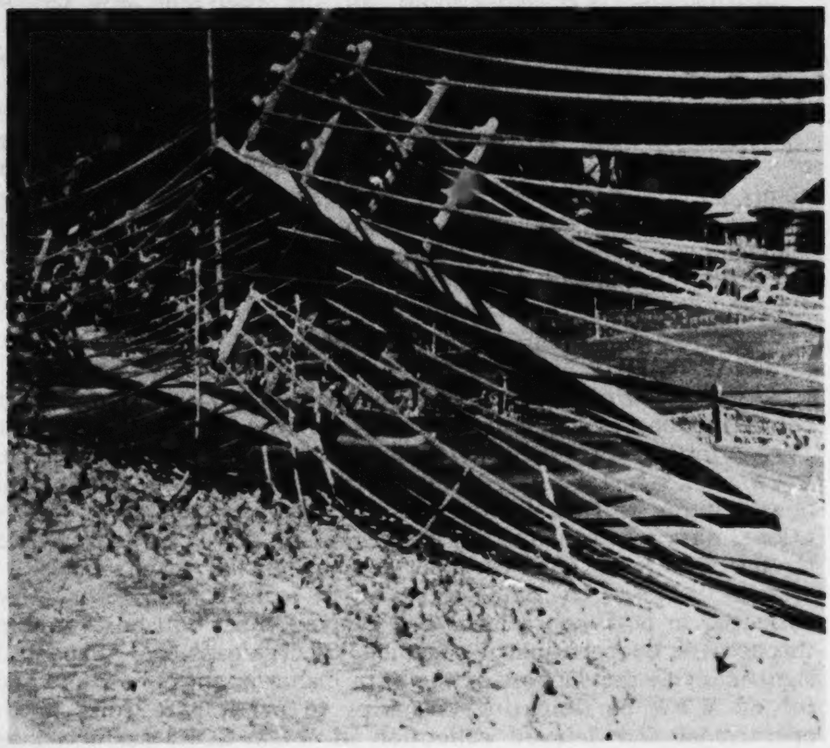
International Plans. During its fourth session in February 1977 the Intergovernmental Panel on the FGGE (IPF) adjusted the time schedule for the FGGE observational phase calling for a Build-up Year beginning in December 1977, followed by an Operation Year beginning in December 1978 and lasting for a full year. Two periods during January-February 1979 and May-June 1979 have been designated for intensive observing. FGGE special observing systems, described earlier, are planned for operation during these periods.

The GARP Activities Office (GAO) of the WMO, which provides day-to-day international planning and coordination of the FGGE, presented to the fourth session of the IPF a second iteration of the summary version of the International Implementation Plan for the FGGE (Part A) and a draft outline of the more detailed International Operation Plan for FGGE (Part B). This latter document, when completed, will provide the detailed deployment and operations plans for each of the FGGE Observing Systems.

During the past year, plans for the real-time and delayed components of the FGGE data management flow were specified in considerable detail in the preliminary data management plan prepared by experts at the Third Data Management Meeting in December 1976. This plan has been distributed to all Members of the WMO for their comments. Commitments from countries and organizations have been obtained for all other delayed data flow components. Operations plans for each component have been included in the data management plan. A series of data management systems tests and evaluations have been proposed and tentatively scheduled, beginning with pre-operational tests during 1977, an evaluation of the delayed data flow during May-June 1978, and culminating in end-to-end tests during each Special Observing Period to evaluate the quality of all FGGE research data.

Pre-operational systems tests began in April 1977. FGGE data collection, processing, and archiving activities will begin in January 1978. Initial data sets will include observations primarily from WWW GOES surface-based and space-based systems. Data from new systems will be included as they become available. Operational data sets required for FGGE will be produced and archived by the WMC's as part of their responsibilities within the WWW system. Research data sets, which consist of observations collected in both operational and delayed time, will be assembled through the cooperation of a number of organizations. Especially significant to the success of the data management flow is the need for all WWW participating countries to participate fully in the operational and delayed collection of WWW GOES surface-based data. A number of research organizations are expected to participate in the production of research analyses. All FGGE research data sets will be archived in the World Data Centers A and B for Meteorology.

__U.S. Participation.__ The U.S. Federal Committee for Meteorological Services and Supporting Research established guidelines for the agencies participating in the FGGE and assigned leadership responsibilities for overall program coordination to the Department of Commerce, NOAA, preliminary planning on FGGE to NASA, and university support of FGGE-related activities to NSF. In October 1974, the Department of Commerce established the U.S. FGGE Project Office as the interagency organization responsible for coordinating U.S. participation in FGGE and preparing detailed implementation plans. In addition to conducting the Data Systems Test, NASA prepared a U.S. Plan for Participation in FGGE, which initially identified U.S. intentions for participation in FGGE and the responsibilities of U.S. organizations. The U.S. FGGE Project Office, under the Department of Commerce, will prepare the final U.S. implementation plans in its role as U.S. National Coordinator. NSF is continuing to work with university groups to ensure maximum participation of U.S. scientists in FGGE research planning activities.



The severe winter of 1976-1977 disrupted whole cities, isolated rural areas for weeks and emphasized our vulnerability to severe weather. International Program of the World Weather Watch contributed significantly to national efforts to understand and forecast crippling storms.

The main U.S. contributions to the observing systems for FGGE are the continued implementation and operation of U.S. components of the WWW, including two operational geostationary satellites (GOES) and a new generation of operation polar-orbiting satellites (TIROS-N); the temporary implementation of upper air sounding stations at six islands on the Pacific; the provision of technical and financial assistance to developing countries under the Voluntary Assistance Program to improve the WWW in areas where major deficiencies exist in observing and telecommunications; partial funding for a shipboard balloon borne upper air sounding system; the development and implementation of an aircraft dropwindsounding system to obtain direct wind observations in the equatorial tropics; a tropical constant level balloon system to complement the aircraft dropsonde program by providing winds and temperatures above the aircraft flight levels, and a Southern Hemisphere Pacific Ocean buoy program. The latter system is to obtain reference level measurements, in particular surface barometric pressure and sea surface temperature measurements;

Return to the drought of the 30's? Several years of abnormally dry weather has created conditions in some areas of the United States reminiscent of the dust bowls. The lack of rain, affecting wide areas of the world, has received special priority within the WMO for improved programs to understand the phenomena.

important for maximum utilization of vertical profiles of temperature and wind vectors derived from satellite observation. NASA's experimental satellite program is planned to contribute important observations required for FGGE.

United States participation in processing, analyzing, and archiving the FGGE data will be equally important to the success of FGGE. To the extent possible, the agencies responsible for observing systems will acquire and process the data into meteorological parameters and communicate the data over the GTS for operational use by NMCs throughout the world. In the United States, the NMC plans to expand its operations during the FGGE observational period to make global analyses and forecasts of several days duration using as much of the new data as possible. United States agencies also plan to produce, in delayed time, complete data sets for their respective satellite and special observing systems and to forward the data sets to an international organization responsible for producing the FGGE research data set. The Geophysical Fluid Dynamics Laboratory (GFDL) of NOAA plans to perform routine delayed analyses of the FGGE archives. The National Climatic Center of NOAA plans to archive and make available for worldwide distribution all operational and research data sets produced by countries and organizations participating in FGGE, including those produced by NMC and GFDL.

Perhaps the most critical U.S. participation in FGGE will be in planning and conducting research and numerical experimentation using the FGGE data sets. A number of U.S. institutions plan significant research efforts, including the National Center for Atmospheric Research supported by the NSF, the Goddard Institute for Space Studies of NASA and the NMC and GFDL of NOAA. NSF will supplement programs of the major modeling groups by supporting activities of the individual scientists who will use the FGGE data sets.

INTERNATIONAL CLIMATE PROGRAM ■

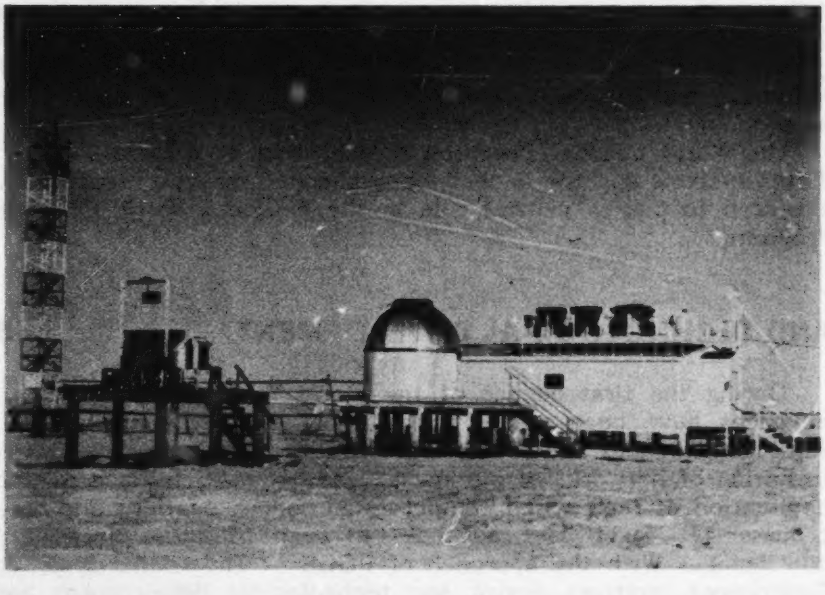
As the demands for goods and services in society approaches closely the capacity to produce them, climatic events have an increasingly important effect on either demand or supply and can result in serious or even catastrophic consequences. These consequences are both national and international in scope, are manifested in regional and local shortages, disruptive to the delivery systems, and often result in rapid increases in prices. The end results are debilitating effects on the domestic and international economy that contribute to higher unemployment, increased inflation, and impacts on foreign policy.

Examples of recent severe climatic conditions and some of their effects over the past few years are:

- The unusually severe 1976-77 winter in the eastern United States which resulted in unprecedented demand for natural gas for heating; the closing of industrial plants and schools in areas of severe gas shortage with resultant higher unemployment; frozen waterways over much larger areas than "normal," interrupting the delivery of oil, fuel, and other supplies; disruption of normal services, such as in Buffalo, New York; and creating higher than "normal" risks of spring flooding.

- The continuing drought in the western United States has lessened the capacity to produce food; reduced the amount of water available for production of hydroelectric power at a time when other energy supplies are either in short supply (as in the case of coal-fired plants inoperative for environmental reasons) or in a stage of rapidly increasing costs (oil); and lead to severe shortages and rationing of drinking water in central and southern California cities.
- The severe crop failures in the Soviet Union in 1972 and again in 1975, which greatly increased demands for the export of grains from the United States and other exporters, resulted in higher prices in the international grain market, reduction in available grain surplusage and contributed to inflation.

During the past few years, both the Executive Branch and the Congress have directed increasing attention toward the development of a comprehensive National Climate Program. A proposed interagency Climate Program Plan is under consideration by the President's Office of Science and Technology Policy, and



The Barrow Observatory, in Barrow, Alaska, is one of the four U.S. Observatories which monitor the background level of atmospheric trace constituents at remote locations. These measurements are important for climate studies.

several versions of draft legislation establishing a National Climate Program are under consideration in both houses of the Congress. The inherently international scope of climate problems and their solutions has been explicitly recognized in these various proposals and their associated hearings.

International activities to develop a coordinated program to address climate-related problems have been proceeding concurrently with national activities. The World Meteorological Organization has been working closely with several international organizations, including the Food and Agriculture Organization, the United Nation's Environmental Program, the International Oceanographic Commission and the International Council of Scientific Unions, to formulate specific programs.

A Climate Dynamics Subprogram of GARP was initiated in 1974 to focus international scientific efforts directed towards an understanding of the physical basis of climate and climatic variations. This subprogram has successfully attracted the attention and interest of many of the world's leading environmental scientists, and some seminal conferences and publications have resulted which place the scientific problems in much clearer perspective. A Climate Dynamics program plan is in preparation for consideration by interested countries within the next year. The opportunity afforded by FGGE -- The Global Weather Experiment to make early progress on Climate Dynamics problems also has been emphasized.

At its meeting in June 1977, the WMO Executive Committee approved the outlines of a World Climate Program, and took steps to insure that a detailed plan would be available for consideration by the Executive Committee next year and by the quadrennial Eighth Meteorological Congress in 1979. Plans for a high-level scientific and technical World Climate Conference also were adopted.

The World Weather Program, through both the World Weather Watch systems and the Global Atmospheric Research Program, is expected to play a central role in the emerging World Climate Program.

SYSTEM DESIGN AND TECHNOLOGICAL DEVELOPMENT ■

During the first decade of the World Weather Watch, major advances have been made; for example, by combining remote sensing techniques and operational satellite platforms, through the initiation of networks of automatic weather stations, and by the application of high speed computers to communications and data processing. Significant advances in each of these areas are continuing. With the approach of FGGE -- The Global Weather Experiment, systems design and technological development has focused on new systems or enhancing old ones to provide the required extensive data base. Technology under development to provide this data base includes polar-orbiting and geostationary satellites and their associated sensor systems, constant level balloons, aircraft dropwindsonde systems, automated commercial aircraft systems, land-based remote-sensing devices, automatic meteorological observing stations, and data buoys. NASA, NOAA, NSF, ERDA, and the Department of Defense are participating in these efforts.

■ Satellite Systems

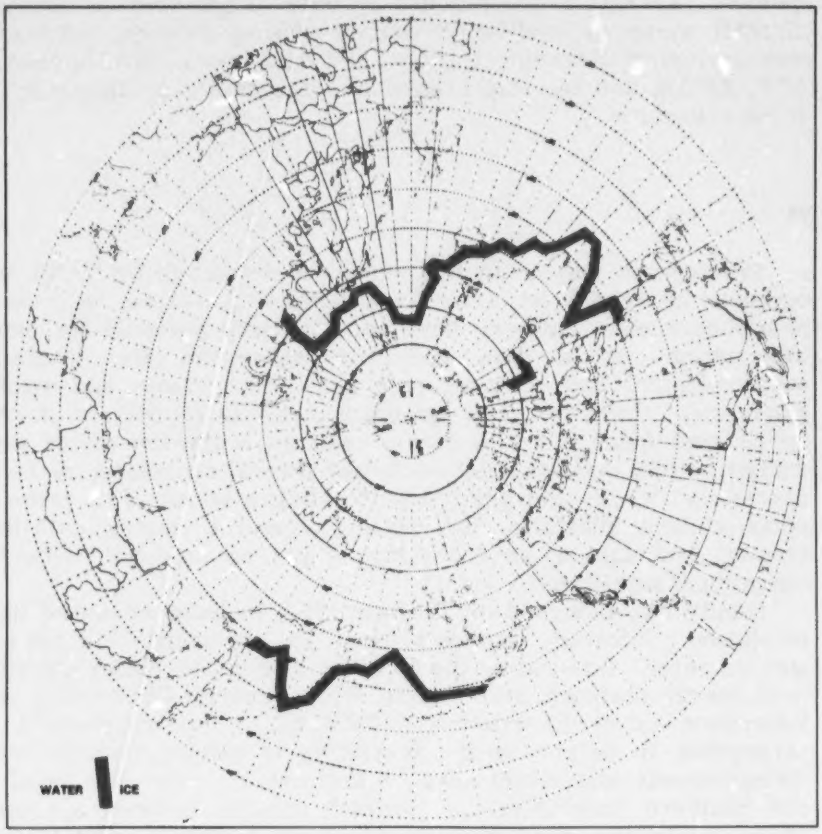
Synchronous meteorological satellites developed by NASA and operated by NOAA comprise the present U.S. system to provide nearly continuous imagery from geostationary altitudes for cloud information and a data collection subsystem for obtaining meteorological and oceanographic data from in-situ and mobile platforms. Currently, two geosynchronous satellites are in the operational mode and two are in orbit on a standby status with partial system outages after each had several successful years of operation. NASA uses the NIMBUS satellite series as its primary polar-orbiting platform for testing research instrumentation, sensors, and data applications that might be used with NOAA's operational satellites.

NIMBUS 6, launched on 12 June 1975, includes advanced high resolution infrared sounders and a scanning microwave spectrometer. Integral to the NIMBUS 6 program, NASA and NSF have jointly designed the Tropical Winds, Energy Conversion, and Reference Level Experiment (TWERLE). This experiment is attempting to determine the feasibility of making tropical wind measurements and establishing an atmospheric reference level in the Southern Hemisphere. Constant density balloons are used which incorporate random doppler-location techniques and a radio altimeter for height determination. This balloon system contributed significant data to DST in preparation for FGGE.

To keep pace with the needs of GARP and the WWW for environmental data, NASA and NOAA have initiated the joint development of a third-generation polar-orbiting satellite (TIROS-N) program. The current NOAA operational polar-orbiting satellites (ITOS) are not large enough to carry the advanced operational version of present day instruments or the oceanographic and hydrologic instruments now being developed in NASA's research and development program. Those advanced instruments, with their improved resolution and accuracy, are needed to provide inputs into numerical models that form the basis for environmental monitoring, warning, and prediction programs.

The design and instrumentation of elements of the TIROS-N system is a cooperative effort among the United States, the United Kingdom, and France. The detailed design of the spacecraft uses technology developed by both NASA and the Department of Defense. The United Kingdom is furnishing an infrared three-

GARP/DST NIMBUS-5 ESMR ARCTIC
PACK ICE BOUNDARY JAN 15-22, 1975



Differing emissivity between sea ice and open water enabled the sensors aboard Nimbus-5 to accurately measure the boundary based on emitted microwave energy. The extent of sea ice cover is very useful for general circulation models.

channel stratospheric sounding unit to provide information on the atmospheric region extending from 20 kilometers to about 50-55 kilometers. France will furnish a data-collection and platform-location system (Argos) for installation on the TIROS-N spacecraft.

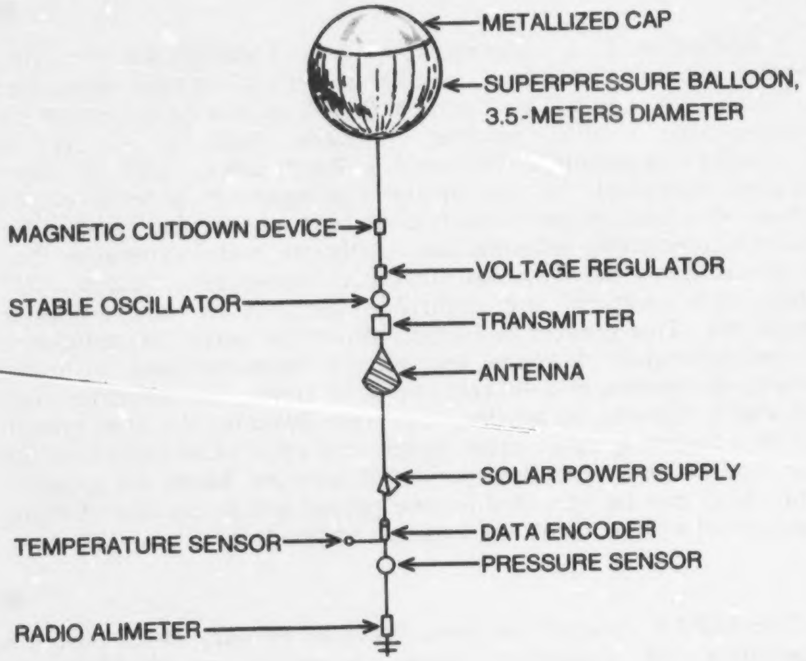
NAVAID Systems

To obtain upper atmospheric wind and thermodynamic information, the operational surface-based WWW observing system relies primarily on balloon borne systems. A balloon carries temperature, humidity, and pressure sensors aloft and data are relayed to the ground over an FM radio link. Either a small radar or a radio direction finder can track the balloon/sensor system to obtain wind data as the balloon rises and drifts. Because of size, weight, or stability requirements for the tracking antenna, this system is not useful on ships or aircraft. Both of these latter are essential components of the observing system being assembled for FGGE, especially to obtain tropical wind data.

An alternative is to use wide ranging radio navigation (i.e., NAVAID) systems -- such as Loran or Omega -- to locate successive positions of the balloon or aircraft dropped parachute system and calculate the upper level winds. During GATE, early versions of both aircraft -- dropwindsounding and balloon-sounding systems were used. The Department of Commerce, and NSF have been developing further these two systems for extensive use during FGGE.

Successful aircraft tests of the dropwindsonde were conducted in March 1977 and the system is in the final stages of evaluation. It is planned that these systems will be deployed on at least ten

NIMBUS RAMS PLATFORM
TWERLE BALLOON


METALLIZED CAP
SUPERPRESSURE BALLOON, 3.5-METERS DIAMETER
MAGNETIC CUTDOWN DEVICE
VOLTAGE REGULATOR
STABLE OSCILLATOR
TRANSMITTER
ANTENNA
SOLAR POWER SUPPLY
DATA ENCODER
TEMPERATURE SENSOR
PRESSURE SENSOR
RADIO ALIMETER

Nearly 450 of these constant-level balloons were launched from tropical sites and one mid-latitude site in the Southern Hemisphere and were tracked by instruments on Nimbus-6. Data gathered included temperature, pressure, geometric height, and winds (at 150 mb). With the height of the 150 mb level determined, information was provided for determination of the energy conversion from potential to kinetic.

aircraft operated by the Departments of Defense and Commerce during FGGE -- The Global Weather Experiment. A prototype shipboard Modular NAVAID System for FGGE is being built under contract and work is underway that will lead to production being started in November 1977.

Constant Level Balloon System ■

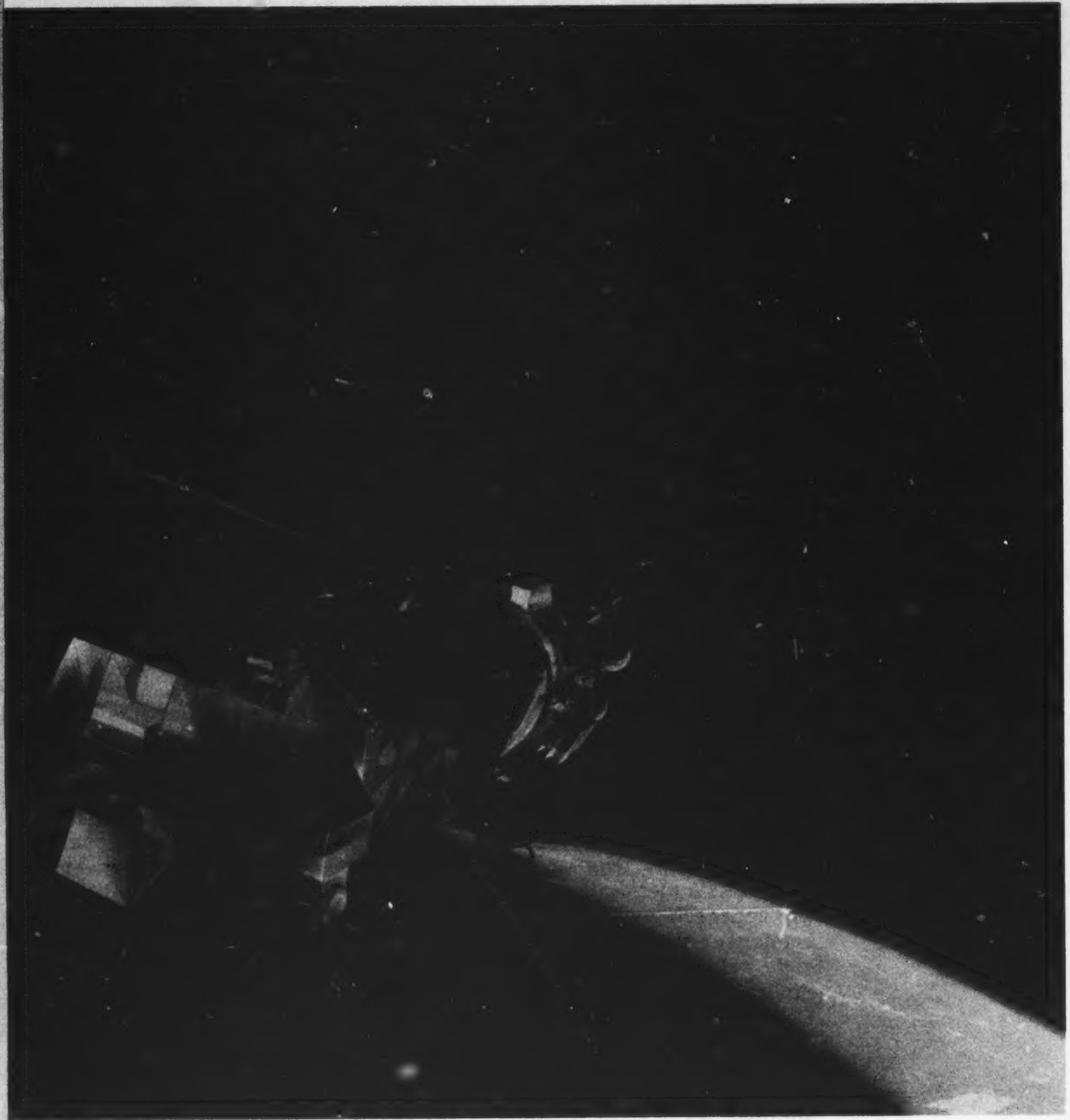
The Tropical Constant Level Balloon System for FGGE is intended to complement the aircraft dropwindsonde program and the WWW upper air sounding systems. Wind and temperature data will be obtained at about 47,000 feet for the zone 20 degrees north to 25 degrees south latitude. Approximately 300 balloons are to be launched during the 1979 operational year of FGGE. The locations of the balloons and ground data processing will be provided by France using their Argos Data Collection and Platform Location system aboard the TIROS-N system of polar-orbiting satellites. The National Center for Atmospheric Research is developing the balloon system with funding provided by the Department of Commerce and NASA.

Local User Terminal ■

A prototype of a high-resolution ground station for receiving weather pictures direct from weather satellites has been developed by NASA. The Local User Terminal (LUT), as it is called, is able to receive high quality weather pictures from a variety of meteorological satellites currently in Earth orbit. LUT has been designed especially for use by meteorologists in underdeveloped nations who must depend wholly or in part on satellite systems for weather-forecasting information. Although more expensive than its predecessor, the Automatic Picture Transmission system, LUT offers both daytime and nighttime pictures of much greater resolution. This greater resolution allows for better identification of meteorological features and allows meteorologists to make better assessments in a shorter period of time. For countries such as Iceland, Canada, Argentina, and New Zealand, the new system will be of even greater value in ice and snow observations which may lead to improved environmental services based on satellite data. LUT can be operated by one person and is capable of being transported and set up at any location on the globe.

ASDAR/AIDS ■

The ASDAR concept has been discussed earlier. NASA and the Department of Commerce have cooperated to develop the capability of obtaining meteorological information at flight level from instruments carried on wide bodied jet aircraft (B-747 and DC-10). For the Aircraft Integrated Data System (AIDS), the data are stored on cassette tape and recovered after the flight. ASDAR relays the data hourly to a geosynchronous satellite.



TIROS-N, the next generation Polar Orbiting Satellite System, will be launched in the fall, 1978. Timed to be operational at the start of The Global Weather Experiment, TIROS-N will provide images of the earth and weather systems, vertical profiles of atmospheric temperature and moisture, surface temperature, and act as a platform for relaying environmental data from remotely placed observing stations to central facilities. Two satellites as illustrated here will comprise the orbiting portion of the TIROS-N system.

The first of seven ASDAR units designed and built by NASA is flying on a Pan American B-747. During 1977 and 1978, the remaining units will be placed on foreign and U.S. aircraft as part of a WMO sponsored International Prototype Test. Additional ASDAR units will be purchased by the Department of Commerce for use during an International Test and Evaluation Program to be conducted during the FGGE operational year. In addition, approximately 50 aircraft will be equipped with AIDS systems and the data incorporated with the FGGE data base.

Buoys ■

The National Oceanic and Atmospheric Administration is developing and field-testing buoy systems in support of operational and research meteorological and oceanographic programs. Emphasis during this period is on the development, fabrication, and deployment of drifting buoy systems and a family of continental shelf buoys. These buoys will provide data from estuaries and the continental shelf for merchant shipping, fishing activities, marine recreation, and coastal habitation. Instrumentation research is centered on obtaining a capability to remotely sense the atmosphere from a buoy platform and on improving ocean profilers, meteorological sensors, and water quality and wave measurement instruments.

The National Oceanic and Atmospheric Administration on a routine basis conducts a wide variety of studies on applications of meteorological data to improve meteorological services. Special attention is directed toward developing new methods for applying satellite data to environmental analysis and forecasting.

Remote sensing techniques using optical, radar, acoustic and laser systems are being developed by the National Oceanic and Atmospheric Administration. Evaluations are being conducted at several locations to provide a basis for the design of operational systems. A low level acoustic sounder is being evaluated at Denver airport as a means of determining wind shear in the lower levels of the approach zone. The capability for evaluating remote sensing equipment will be greatly increased when the new 300 meter town and related facility is completed in early 1978 at the Environmental Research Laboratories, NOAA site near Boulder, Colorado.

The Energy Research and Development Administration is conducting fundamental studies in instrumentation, such as aerosol generators for testing particle samplers used in high altitude applications. Other techniques for obtaining surface data are also under development including pollutant sensors and radio-telemetering buoys.

3. The United States Program for Fiscal Year 1978

The World Weather Program comprises three areas of activity:

- World Weather Watch Implementation
- Global Atmospheric Research Program
- Systems Design and Technological Development.

The following conventions have been used to identify funds for U.S. activities in support of or contributing to the World Weather Program for FY 1978:

- Funds indicated without parentheses are for projects specifically in support of the World Weather Program.
- Funds indicated in parentheses have been designated by the Federal agency primarily to support programs that meet immediate mission needs, but at the same time fulfill a requirement of the World Weather Program, and would be budgeted even without U.S. participation in the World Weather Program.

All FY 1978 fiscal data in this plan are reflected in the President's budget, and the data shown here should be used for planning purposes only. The scheduling and implementation of the U.S. programs after FY 1978 in support of the World Weather Program are subject to additional analysis and further judgment.

■ WORLD WEATHER WATCH IMPLEMENTATION

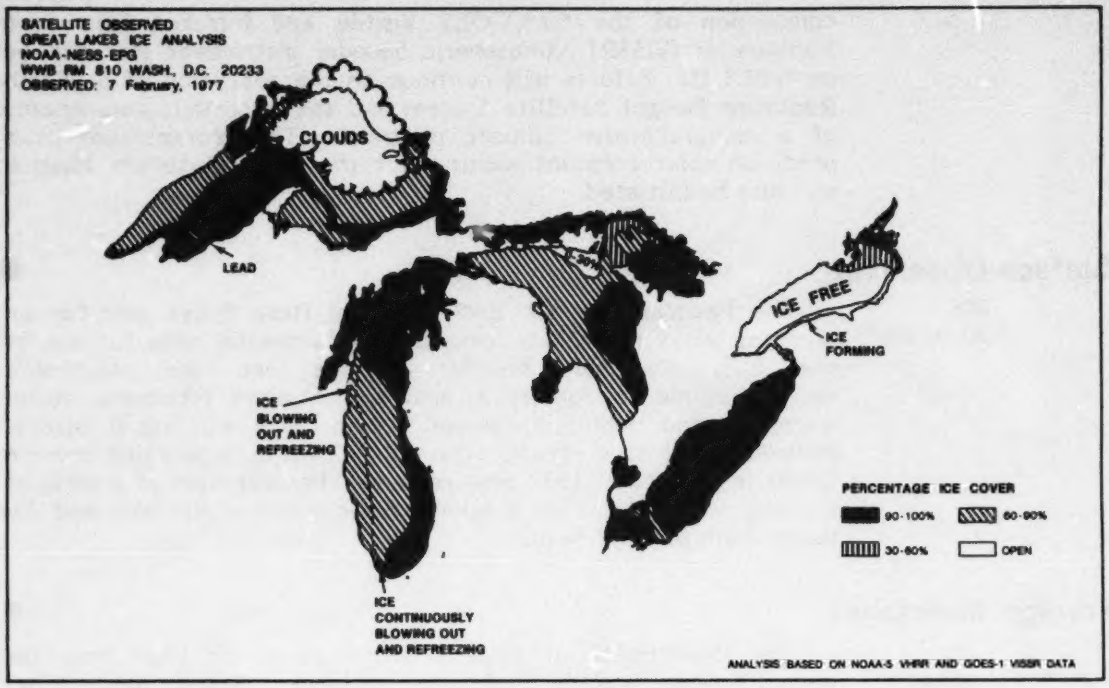
During FY 1978 the U.S. program will focus on (1) maintaining a continuous, two-spacecraft, operational geostationary satellite system, (2) procuring spacecraft and ground equipment for the next generation polar-orbiting satellite system and (3) improving the operational WWW surface-based system in anticipation of FGGE -- The Global Weather Experiment. Assistance will continue to be provided to developing nations to enable them to participate more fully in the World Weather Program.

Satellite Observing

DOC
($86,813,000)
NASA
($7,700,000)

The polar-orbiting satellite system provides cloud imagery and quantitative measurements of environmental variables twice daily in support of environmental monitoring and prediction programs. With two spacecraft the operational geostationary satellite system provides nearly continuous observations of environmental phenomena over most of North and South America and major portions of the Atlantic and Pacific Oceans for more effective warning services. Special evaluations have been conducted by the Department of Commerce to use geostationary images taken at repetition rates as high as once per three minutes. Insight into the formation of severe convective storms has been obtained and is being translated to forecast programs.

NOAA 5, the most current spacecraft in the polar-orbiting IGOS series, was launched in July 1976. GOES 1, the first NOAA funded geostationary satellite, was launched in October 1975 and replaced the Synchronous Meteorological Satellite (SMS) launched by NASA in May 1974. GOES 2 was launched in June 1977 to replace GOES 1 which had a partial systems failure.


SATELLITE OBSERVED
GREAT LAKES ICE ANALYSIS
NOAA-NESS-EPG
WWB RM. 810 WASH., D.C. 20233
OBSERVED: 7 February, 1977
CLOUDS
LEAD
30%
ICE FREE
ICE FORMING
ICE BLOWING OUT AND REFREEZING
PERCENTAGE ICE COVER
90-100%
60-90%
30-60%
OPEN
ICE CONTINUOUSLY BLOWING OUT AND REFREEZING
ANALYSIS BASED ON NOAA-5 VHRR AND GOES-1 VISSR DATA

Images from NOAA-5 (a polar orbiting satellite) and GOES-1 (geostationary) were used to prepare this composite analysis of ice on the Great Lakes for February 7, 1977. These analyses, made available to marine users, have increased the ability to predict when the lakes can be used for shipping.

Major program efforts for FY 1978 will provide for:

- staff and contractor support for the TIROS-N series ground system
- continued procurement of TIROS-N series spacecraft and instruments
- continued procurement of GOES series spacecraft and instruments
- launch services for GOES spacecraft
- operation of both polar-orbiting and geostationary satellite systems.

The NASA is developing the TIROS-N, a third generation polar-orbiting satellite system, to meet stated requirements of NOAA for obtaining quantitative data of the earth's atmosphere on a daily basis. This new system scheduled to be launched in 1978 will include an improved atmospheric sounder with microwave channels to facilitate data retrieval in cloudy areas, advanced multi-channel imagery, and addition of a data collection and platform location capability. Satellite-related efforts will also focus on the completion of the SMS/GOES Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder instrument that will be on GOES D. Efforts will continue on the definition of an Earth Radiation Budget Satellite System and the important components of a comprehensive climate program. The procurement of a precision solar constant monitor for the Solar Maximum Mission will also be initiated.

Surface Observing

DOC
($2,700,000)

The Federal Plan for Environmental Data Buoys specifies an array of buoys to provide synoptic environmental data for use by the U.S. National Weather Service and the worldwide meteorological community in providing weather forecasts, storm warnings, and public advisories. Buoy data will assist marine environmental studies and will aid NOAA in supporting marine industries. The FY 1978 plan calls for the operation of a total of ten deployed buoys in the Regional Basic Synoptic Network and the deployment of an eleventh.

Foreign Assistance

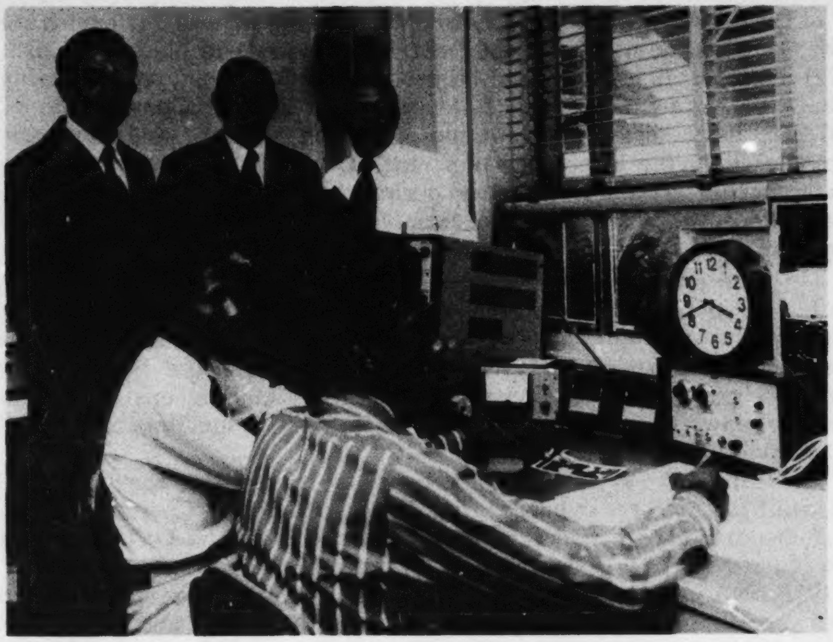
DOC
$2,000,000

The Department of State provides funds for VAP from the annual Foreign Assistance Act appropriation. Except for a direct cash donation to WMO of $135,000, the funds are administered by the Department of Commerce. A total U.S. contribution of $2,000,000 has been requested for this program in FY 1978.

These funds will be used by the United States to provide equipment, services, and fellowships to developing countries. Under this year's program, radio transmitting and receiving equipment will be made available for improving national and international meteorological data exchange; wind-finding radars will be provided in tropical areas for wind data acquisition; long-term and short-term fellowships will be provided to meteorologists in developing countries to increase their capability to use modern equipment and to improve their understanding of atmospheric processes that result in weather and climate change. The United States will also provide new systems for earlier recipients of Automatic Picture Transmission equipment under the VAP to improve their capability to receive direct readout transmissions from NOAA satellites and to provide a capability for intercepting processed data from the GOES system. A start will be made on providing expert services to monitor the operation of the WWW in order to improve its efficiency.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM

During FY 1978 many activities will be conducted to further the goals of the Global Atmospheric Research Program. Data from the



Dedication of the APT station in the Bahamas to receive images from polar orbiting satellites. As part of the United States contribution to the Voluntary Assistance Program in FY 1978, this station and other provided earlier by the United States will be modified to receive both images from the new TIROS-N system and processed information broadcast from the GOES system.

field observational phase of the GARP Atlantic Tropical Experiment, conducted during the 1974 summer season, and the recently completed Data Systems Tests are being processed, analyzed, and interpreted. International efforts to define the research required to advance knowledge on the physical basis of climate and climatic fluctuations will continue. Plans drawn for U.S. participation in FGGE -- The Global Weather Experiment beginning in December 1978 will be amplified and a start made toward implementation. The FGGE build-up phase will begin in December 1977. Research efforts in numerical modeling of the atmosphere and in global monitoring and analysis of critical environmental parameters will be continued.

■ Experiments and Analysis

The National Academy of Sciences U.S. Committee for GARP acts in an advisory role and recommends research programs including field projects that contribute to GARP objectives. The National Science Foundation and the National Oceanic and Atmospheric Adminstration provide equal support to this committee.

DOC	$5,350,000
NASA	$2,155,000
NSF	$6,550,000 ($5,450,000)

During FY 1978 the Department of Commerce will concentrate on (1) using the results of the Data System Tests to plan for FGGE, (2) implementing FGGE and (3) processing, analyzing, and archiving data collected during the field phase of GATE. Compilation of GATE data sets will continue, and the results will be made available to the international scientific community as the work is completed. Research initiated during the past year to provide new and improved insight to the formulation of tropical processes in global atmospheric models will be continued.

The Department of Commerce will continue implementation of its participation in the FGGE. This initiative includes coordinating scientific programs; developing mathematical models and data management systems to accommodate the FGGE data; and procuring special observing systems, including environmental data buoys and special systems to provide supplementary wind observations in the tropics.

During FY 1978, NASA will continue to evaluate results of the Data System Tests in preparation for the FGGE. An Announcement of Opportunity to conduct basic research using the DST data sets was issued in FY 1977; the bulk of the work will take place in FY 1978. NASA will also develop the data processing systems required to contribute relevant data sets from the NIMBUS G and SEASAT A experimental satellites to the FGGE archives.

In FY 1978 the National Science Foundation will continue to support the analysis and interpretation of the data collected during the GARP Atlantic Tropical Experiment (GATE) and the Air Mass Transformation Experiment (AMTEX). The NSF will also continue its support of FGGE -- The Global Weather Experiment, the Polar Experiment (POLEX), the Monsoon Experiment (MONEX), and the Indian Ocean Experiment (INDEX), a planning program in support of the oceanographic part of MONEX.

The National Science Foundation and the Department of Commerce have agreed to support university research utilizing GATE data. Therefore, many of the grants will be jointly funded by NSF and the Department of Commerce with grant administration provided by NSF.

Atmospheric Modeling and Simulation

DOC
($9,012,000)
DOD
($2,432,000)
ERDA
($1,100,000)
NASA
$2,845,000
NSF
$4,050,000
($3,650,000)

A significant research program to develop numerical models of the global atmosphere is being conducted by a number of Federal agencies, several universities, and NCAR. Although several models are now operational, further refinement of these models is needed to reproduce atmospheric motions with greater fidelity to determine the ultimate limit of weather predictability, to assess the effect of man's activities on climate, to develop methods for using nonsynchronous data as bases for predicting large-scale motion, and to design an optimum composite meteorological observing system for routine numerical weather prediction.

During FY 1978 ERDA is continuing its effort to develop a comprehensive model for estimating long-term air concentrations of and resultant population exposure to pollutants injected into the atmosphere from anywhere on the globe. Such a model is needed to evaluate the effects of alternative means of energy production on local, regional, and world populations.

Analyses of stratospheric concentrations of radioactive debris from nuclear weapons tests will be continued to provide data to assist in developing numerical global circulation models. A simple circulation model based on the flux-gradient relationship has been developed, and the estimated distribution of radioactive materials from recent high yield nuclear tests will be used as input to determine the model's limitations in estimating depletion and/or build-up of possible man-made contaminants in the stratosphere. Investigations are also being conducted to assess the vulnerability of the stratosphere, with respect to changes in ozone concentration, resulting from injections of fluorocarbons and oxides of nitrogen.

Studies are being conducted to understand the atmospheric and oceanic budgets of energy, angular momentum, and mass and to apply this understanding to problems of the global distribution of trace substances, both active and passive, so that the complete cycle of these trace constituents can be outlined.

The physical laws that govern the behavior of the atmosphere and oceans must be better understood and expressed in mathematical terms to provide continued improvements in weather forecasting. The Department of Commerce conducts a major research program to accomplish this at the Geophysical Fluid Dynamics Laboratory (GFDL). Through the use of advanced digital computers and mathematical models of the earth's oceans and atmosphere, models will be developed that simulate the behavior of the entire ocean-atmosphere system of the earth. This research on large-scale circulation, together with the use of weather satellites, will provide the foundation for future global weather forecasts. The new Advanced Scientific Computer recently placed in operation will enable GFDL to establish more firmly the scientific basis for constructing physically precise models of the atmosphere-earth-ocean system. The models will then be used to simulate the behavior of geophysical phenomena reaching from the atmosphere's boundary layer, near the earth's surface, upward to the mesosphere, and from the oceans' surface down to deep ocean currents. Phenomena ranging from small scale, which would affect a single city, to the earth's total circulation will be studied with the purpose of developing prediction techniques.

A second phase of the environmental modeling work involves laboratory and field investigations of atmospheric turbulence and diffusion, the motion of pollutants from point and volume sources, and the influence of urban areas on these processes. The results of this work provide knowledge required for forecasting local weather conditions as well as for providing meteorological understanding to support air pollution monitoring and abatement decision.

The Department of Defense will continue to provide indirect support through their atmospheric modeling and simulation programs. This will include a global extended range environmental prediction system, tropical cyclone forecast modeling, and the development of computer programs to process SEASAT data in real time.

During FY 1978 NASA, with the support of NOAA, will continue to conduct tests of data utilization to determine the limitations and difficulties in the preparation of global data sets with the coverage and accuracy required for FGGE. The objectives of these tests are to provide system designers with information on the overall performance and effectiveness of observing systems and the consequent handling and processing of the data. The Goddard Institute for Space Studies will conduct theoretical studies and real-time data experiments for the optimization of satellite observing systems, extraction of maximum meteorological information from spaceborne sensors, and application of this information to improved numerical prediction of atmospheric processes.

The National Science Foundation will continue to support GARP-related research at universities and at NCAR to improve numerical modeling and conduct studies of predictability. The modeling efforts being supported include models of turbulence, boundary layer phenomena, large-scale prediction, cumulus convection parameterization, and the general circulation. Predictability studies range from the most basic, analytic studies of the equations of motion and energy to examination of the statistical response of the NCAR general circulation model to a variety of perturbations.

Many studies supported by NSF combine numerical modeling and observational analysis and interpretation to enhance the overall understanding of the global atmospheric-oceanic system. One goal of the Global Extended Range Prediction System is to improve the accuracy of forecasts over ocean areas for longer periods of time, initially to 72 hours and later to 10 days and beyond. Evaluation and selection will continue of numerical models of the atmosphere, ocean, and ionosphere that deal with exchange processes and the distribution of significant characteristics of the air-sea interface and of the marine planetary boundary layer.

The NSF-sponsored modeling research includes such diverse efforts as validating a detailed, mesoscale, air-sea boundary layer model using GATE data; investigating the dynamics and energetics of intense cyclone development off the east coast of the Asian continent using AMTEX data; applying the entire general circulation model to examine atmospheric responses to sea-surface temperature anomalies, as well as other perturbations in the forcing function; and developing and testing cumulus parameterizations for large-scale models.

National Science Foundation grantees are using model simulations to plan observation programs for MONEX and FGGE. For example, meteorologists and oceanographers are working together to analyze models and use the results to examine the atmosphere, land, and ocean interactions involved in the perturbations of the Somali current in the southwest monsoon. These studies will be used in planning, analysis, and interpretation for MONEX.

■ Global Monitoring and Climate

NSF	$350,000	($1,060,000)
DOC	$135,000	($1,755,000)
ERDA		($2,414,000)
EPA		($4,000,000)
NASA		($5,274,000)

The United States is conducting programs to monitor atmospheric constituents, including trace elements, to determine their influence on climate as well as their impact upon the quality of the environment.

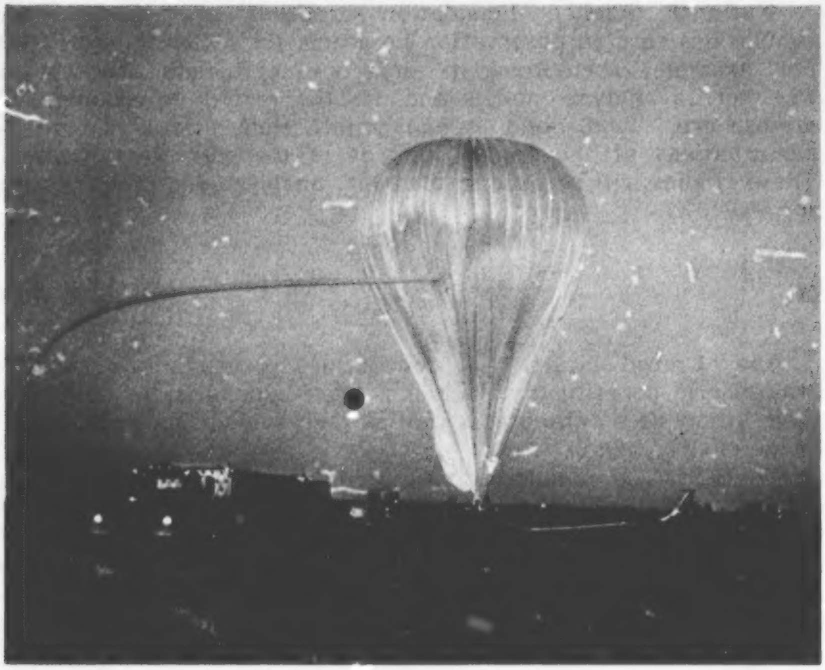
The ERDA is conducting measurements of the monthly fallout rate of radionuclides by sampling at about 125 land stations throughout the world. Data are used to study the global fallout rate of strontium-90 and to determine the latitudinal deposition increments for assessing the fallout inventory.

Twenty of these stations are located along the 80th meridian from the South Pole to Thule, Greenland, and use Hi-vol samplers for collecting air contaminants. The acidity of precipitation is also measured at four sites in the northeastern part of the U.S. as part of the MAP3S program.

Deposition of a number of non-nuclear energy-related pollutants is being studied on the east and west coasts of the U.S. and in the midwest. These studies have been extended by installing instruments at the Department of Commerce's baseline stations at Mauna Loa and American Samoa to investigate baseline levels of various pollutants. Data are also accumulated on surface air concentrations of lead, iron, nickel, and vanadium over a large range of pollution levels found on the earth's surface from highly polluted industrial urban areas to the remote "global baseline" stations such as Mauna Loa or American Samoa.

The high altitude sampling program will be conducted by aircraft (Project Airstream) from 75°N to 10°S latitude in the Western Hemisphere and by balloons (Project Ash Can) launched from Panama, Alaska, and New Mexico. These programs will provide data on selected radionuclides from altitudes of 12 to 27 kilometers. The aircraft measurements will also provide a profile of the vertical concentration of pollutants.

A wide spectrum of radionuclides is being measured on a continuous basis at Richland, Washington, and at Barrow, Alaska. Stable elements are also being measured daily to determine their variations in concentration with time. Ground-level sampling of atmospheric tritium and tritiated water vapor will be continued on a twice weekly schedule at Mauna Loa, Hawaii; Miami, Florida; Fairbanks, Alaska; and New Zealand.



A stratospheric balloon is ready to be launched for the Energy Research and Development Administration's Project Ash Can. Samples of stratospheric radioactivity and stable trace constituents are obtained at altitudes from 70,000 to 90,000 feet. Both aircraft and balloons are launched from several sites in the Northern Hemisphere on a seasonal basis as part of ERDA's long standing High Altitude Sampling Program.

The Department of Commerce is planning to establish a Climate Diagnostics Center (CDC). Essential first steps required for improvements in climate forecasts include exploration of new applications of statistical analysis techniques, diagnostic case studies of selected recent short-term climatic fluctuations, new studies of physical-statistical relationships between atmospheric and oceanic anomalies, and increased use of satellite observational techniques. These needs will be met by the CDC. A CDC is needed to form and collocate a team of specialists, now scattered according to scientific specialization and agency mission, to lead in interpreting information from nearly disparate sources for complementary and immediate application to climate assessments and predictions. Through such a center, new and existing applications in climate research, diagnostic studies, analyses and forecast procedures would be proposed, tested, and effected more directly, saving both time and expense.

Important objectives of the Department of Commerce climate measurement program are to make measurements and conduct the research and analysis required to identify the trends in atmospheric trace constituents based on data from the global monitoring network, specifically to establish baselines of atmospheric trace constituents in the polar and tropical zones by 1978, and in mid-latitude zones by 1986; to determine man's influence on global weather and climate due to the increasing industrialization of the world using baseline measurements to develop model parameterization and to provide the basis for verification of these models; and to begin relating the trends and other variations in atmospheric trace constituents to changes in weather and climate on scales of 1 to 10 years by establishing by 1980 specific trends and cyclic behavior, and by the year 2000 establishing complete global budgets for atmospheric trace constituents.

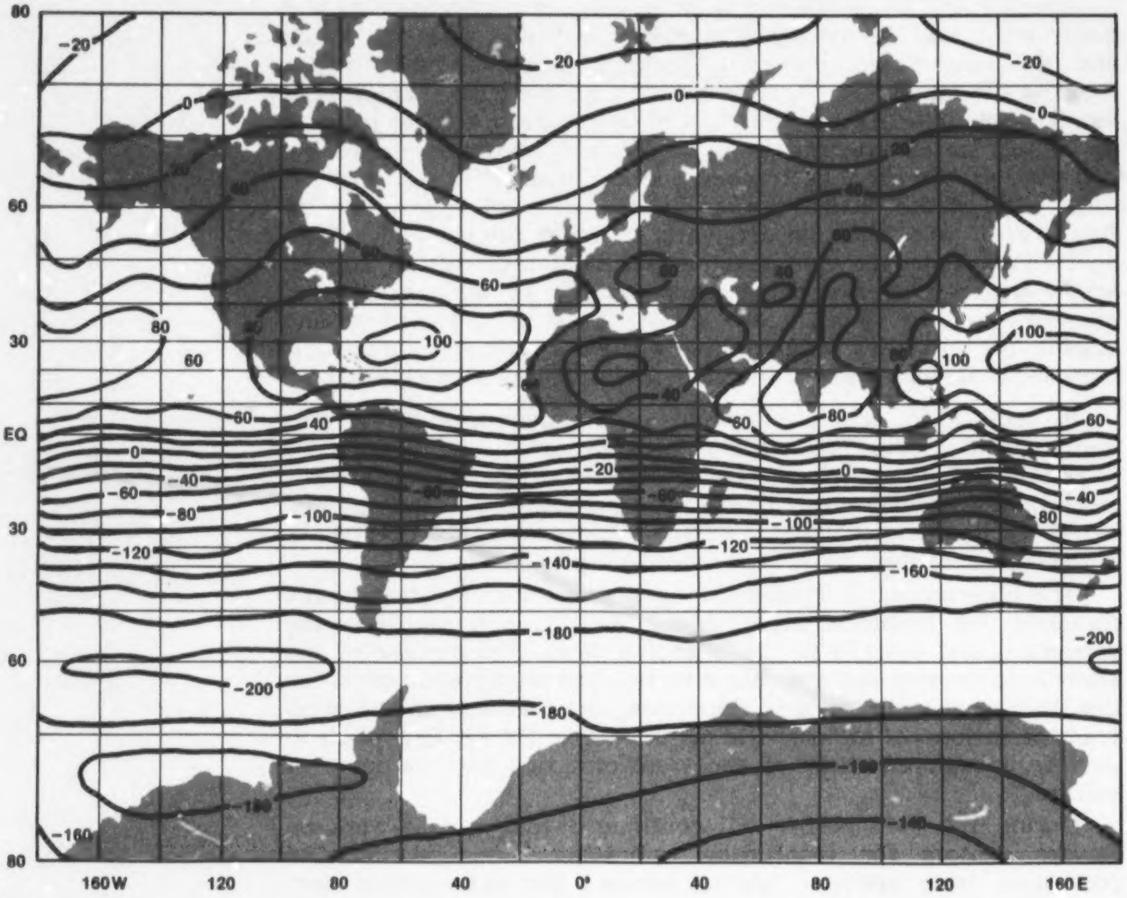
Climate will be monitored by using existing worldwide data and information sources available through the World Weather Watch and specialized observational projects such as the NOAA Geophysical Monitoring for Climate Change program. Traditional indicators of climate and the ones most obviously tied to impacts on United States' interests (e.g., weekly and monthly temperature and precipitation) will be tracked and analyses will be tailored for users such as the NOAA Center for Climatic and Environmental Assessment and the Departments of Agriculture and State. Specialized and unconventional climate data sets will be formed and analyzed to gain a better understanding of the processes of climate variability (e.g., in the energetics of the atmosphere and ocean), and made available to those working in climate diagnostics, monitoring systems design, and modeling and prediction research.

In late 1977, the Department of Commerce will host an international intercomparison of total ozone measuring instruments at Boulder, Colorado, cooperatively with the World Meteorological Organization and the International Ozone Commission. In FY 1978, NOAA will assist Iceland, Mexico, Argentina, and Brazil in improvement of their total ozone measuring instruments.

The Environmental Protection Agency, after completion of the Regional Air Pollution Study during FY 77, will continue the processing and analysis of the collected data. The purpose of the study is to develop and evaluate diffusion and prediction models for determining the atmospheric dispersion, and chemical and physical transformations, of atmospheric pollutants. In FY 78, EPA plans to initiate a regional study of the transformation and transport of sulfate.

During FY 1978 NASA will continue developmental work on remote sensors for monitoring atmospheric composition and pollutants from space. Special sensors for determining both gaseous and particulate pollution are being developed and tested for experimental use on NIMBUS G, scheduled for launch in 1978. Advanced atmospheric sounders proposed for the NIMBUS G spacecraft include instruments for measuring the trace constituents and particulates in the atmosphere from the troposphere upward into the mesosphere on a global basis to assess the feasibility of space-mapping and predicting atmospheric pollution. NASA is also conducting studies and in-situ observations directed toward developing techniques for defining and predicting the global distribution of minor constituents in the atmosphere and the effects that changes in this distribution would have on the

GLOBAL NET RADIATION (in w/m²) AS DETERMINED BY THE NIMBUS-6 EXPERIMENT FOR JULY 1975



The map shows the global distribution of the earth-atmosphere system net radiation for the month of July 1975 as measured by the Earth Radiation Budget (ERB) Experiment on Nimbus-6. There is a large surplus of radiant energy in the Northern Hemisphere where it was summer and a large deficit in the Southern Hemisphere and at the polar region of the Northern Hemisphere where outgoing radiation exceeds the incoming.

physical state of the atmosphere. Of particular interest are the effects of contaminant injection into the stratosphere; the emission and dispersal of pollutants and natural trace gases on urban, regional, and global scales in the troposphere; and possible climatic changes resulting from variations in minor constituent concentrations. NASA will conduct concurrent investigations into (1) atmospheric chemistry and physics, leading to the development of dynamic models coupling chemical reactions, atmospheric dynamics, and pollutant diffusion, and (2) atmospheric sensing to provide real data for the mathematical models. The resulting combinations will then be used in experiments to define and predict the time-dependent concentrations and transport of atmospheric pollutants.

The National Science Foundation supports a variety of global monitoring efforts. As part of the International Decade of Ocean Exploration (IDOE) program, scientists working with the North Pacific Experiment (NORPAX) will study long-period, large-scale ocean-atmosphere coupling. Special efforts are being made in NORPAX to monitor the North Pacific Ocean and atmosphere. IDOE also supports the International Southern Oceans Studies (ISOS), which monitor oceanic transports through the Drake Passage. The Division of Polar Programs at NSF supports a NOAA baseline station at the South Pole, which collects data on carbon dioxide, ozone, and aerosols. NSF also supports the daily surface and upper air observations made at the South Pole and McMurdo stations and transmitted routinely to the WWW.

■ SYSTEMS DESIGN AND TECHNOLOGICAL DEVELOPMENT

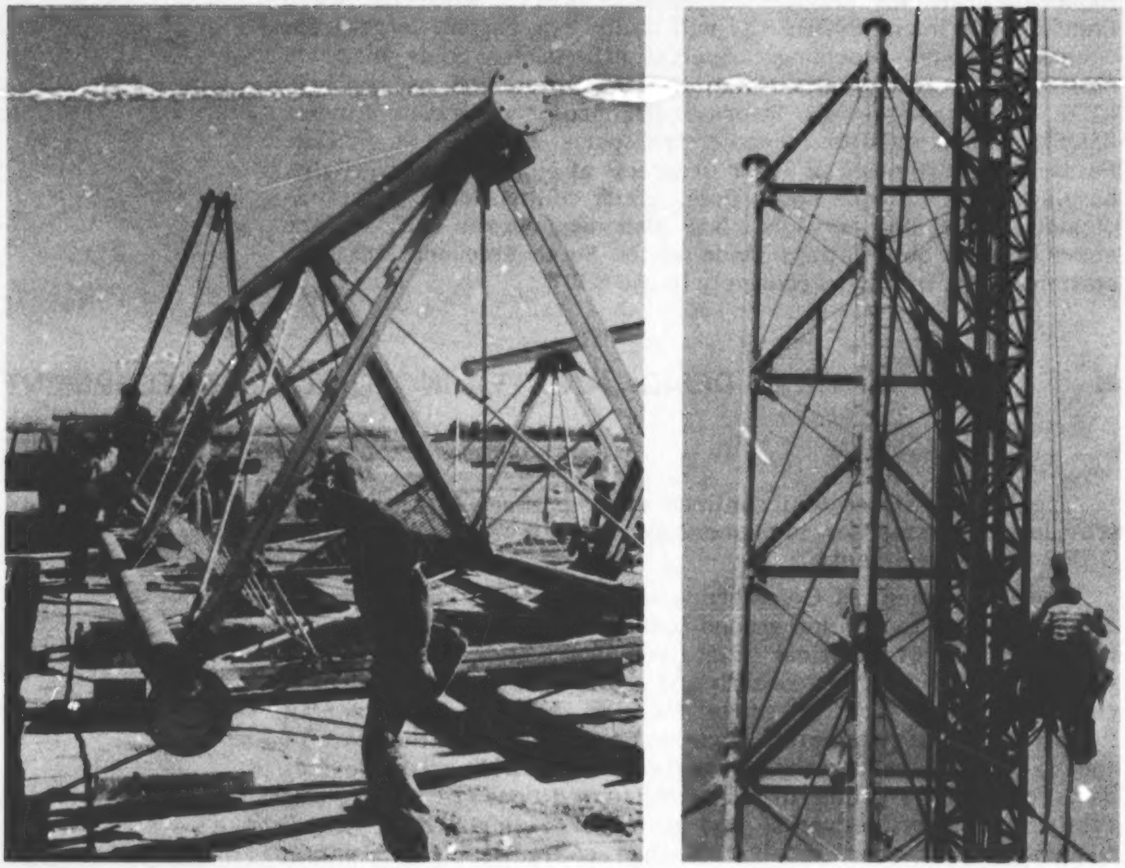
Instrument Development

DOC
($2,992,000)
ERDA
($5,110,000)
DOD
($1,200,000)
NSF
$150,000

The United States will continue a comprehensive program to provide the means for implementing the WWW and conducting GARP field experiments.

The Department of Commerce conducts a research program in remote sensing to develop ground-based techniques for the remote measurement of critical meteorological and oceanographic parameters required by research and service programs. Typically, remote sensing from a single location provides simultaneous measurements of parameters important to weather and the state of the ocean's surface at many points throughout a wide area; provides data continuously rather than intermittently; does not require any costly telemetry networks; and generally is highly automated, requiring fewer operational staff than conventional observation techniques. Considerable success has been achieved in establishing the feasibility of remote sensing of the atmosphere and the oceans using acoustic, radio and optical signals. A Joint Meteorological Observing Facility (JMOF) operating a tall (300 meters) meteorological research tower will, when fully instrumented, provide an essential engineering facility for the evaluation, demonstration, and calibration of remote sensing instruments in support of research and service applications. The JMOF will also be used as a uniquely instrumented field site for conducting new research on atmospheric processes such as convection, cloud formation, precipitation, turbulence, low level wind shear, and the transport and diffusion of pollutants.

The ERDA is conducting fundamental studies to support the development of several instruments for its high altitude sampling program. An electrostatic band-pass aerosol generator for use in testing particle samplers and an improved electrostatic precipitator for high-altitude application are being developed.



The Boulder Atmospheric Observatory includes a 300 meter tall instrumented tower which will be available for experiments in 1978. An early series of experiments planned for the facility is to compare techniques and equipment for obtaining vertical profiles in the lower atmosphere and will be sponsored by the World Meteorological Organization.

Studies are also being continued concerning the application of molecular sieves to sample stratospheric trace gases.

The Department of Defense will continue to provide indirect support through their instrument development programs. These include improvement of meteorological sensors and the development of a lightweight balloon-borne radiosonde for shipboard launch from which a refractive index will be determined.

The development of the Tropical Constant Level Balloon System (TCLBS) by NSF at NCAR is continuing in preparation for FGGE. In this program, the TCLBS designed for the Tropical Wind, Energy Transformation and Reference Level Experiment (TWERLE) will be applied to the FGGE tropical observational system requirements for upper tropospheric wind observations in the deep tropics.

Buoys

NSF
$475,000
($300,000)
DOC
($5,400,000)
ERDA
($450,000)
DOT
($996,000)

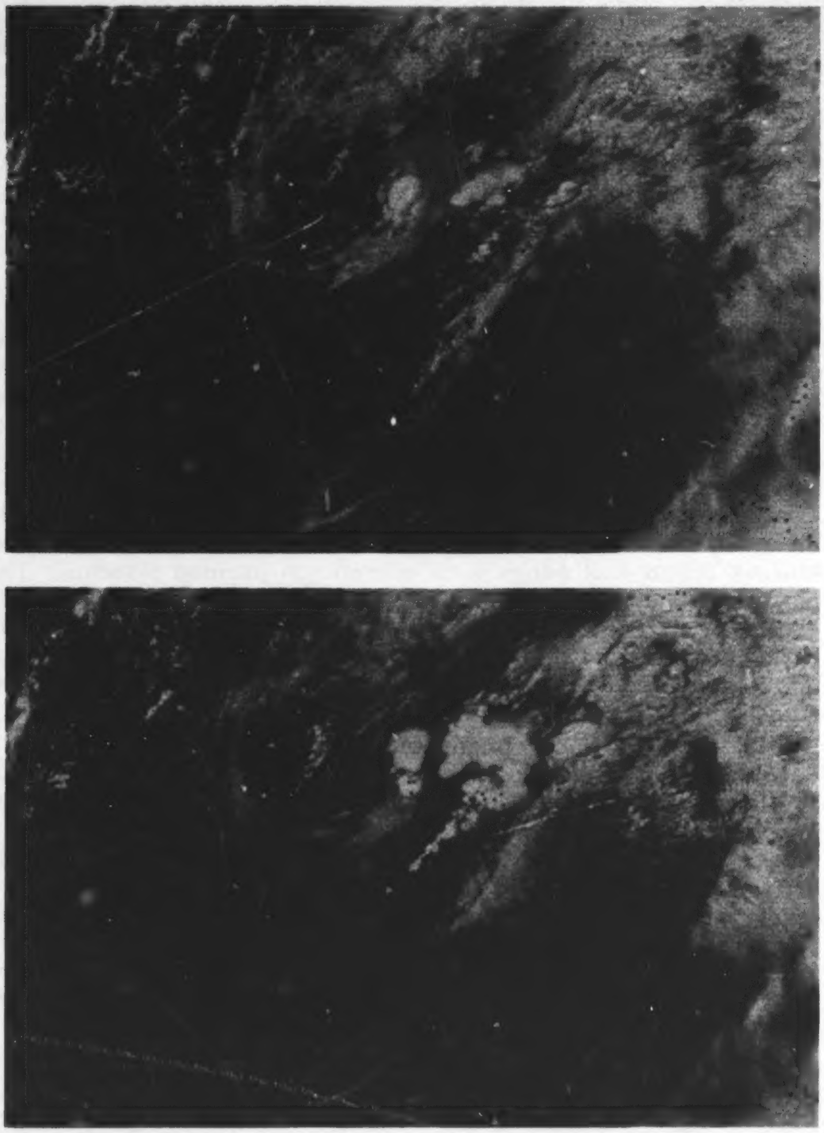
During FY 1978 the Department of Commerce will continue developing, procuring, operating, and maintaining buoy platforms to acquire data in support of basic environmental service programs. These buoys will provide measurements of wind velocity, air temperature, barometric pressure, wave height and period, and subsurface water temperature at six levels. The Department of Commerce will operate and maintain nine buoys that will be in inventory from FY 1975-76 procurements, and equip six existing 40-foot discus hull buoys with operational payload systems. The nine deep-ocean, moored buoys to be operated during FY 1978 consist of six Prototype Environmental Buoys (PEB) located off the Northwest Pacific Coast and in the Gulf of Alaska, two 40-foot discus buoys equipped with PEB payloads off the Atlantic Coast, and one 40-foot discus buoy in the Gulf of Mexico.

NSF and the Department of Commerce emphasis in future development is on drifting and ice buoy systems; remote sensing of the lower atmosphere from buoy platforms; water quality sensors; and improving ocean profilers, meteorological sensors, and wave measurements. NSF, NCAR, and NASA will test an expendable drifting buoy system as a means to provide a pressure-reference level at the surface and surface-water and mixed-layer temperature. Most of these developments will have direct application to the WWW and FGGE. In addition NSF is supporting buoy development for the International Southern Oceans Studies (ISOS).

The Brookhaven National Laboratory, an ERDA laboratory, is operating four radio-telemetering buoys located off the coast of Long Island, New York. These buoys provide data on current speed and direction, sea-water temperature, and conductivity (salinity).

The Department of Transportation, through its U.S. Coast Guard, provides support to the Department of Commerce Data Buoy Program for developing and evaluating data buoy systems.

U.S. Coast Guard vessels deploy, service, and retrieve buoys built for test or operational purposes. Coast Guard radio facilities provide buoys built for test or operational purposes. Coast Guard radio facilities provide communication services serving as collecting sites for data from buoys.

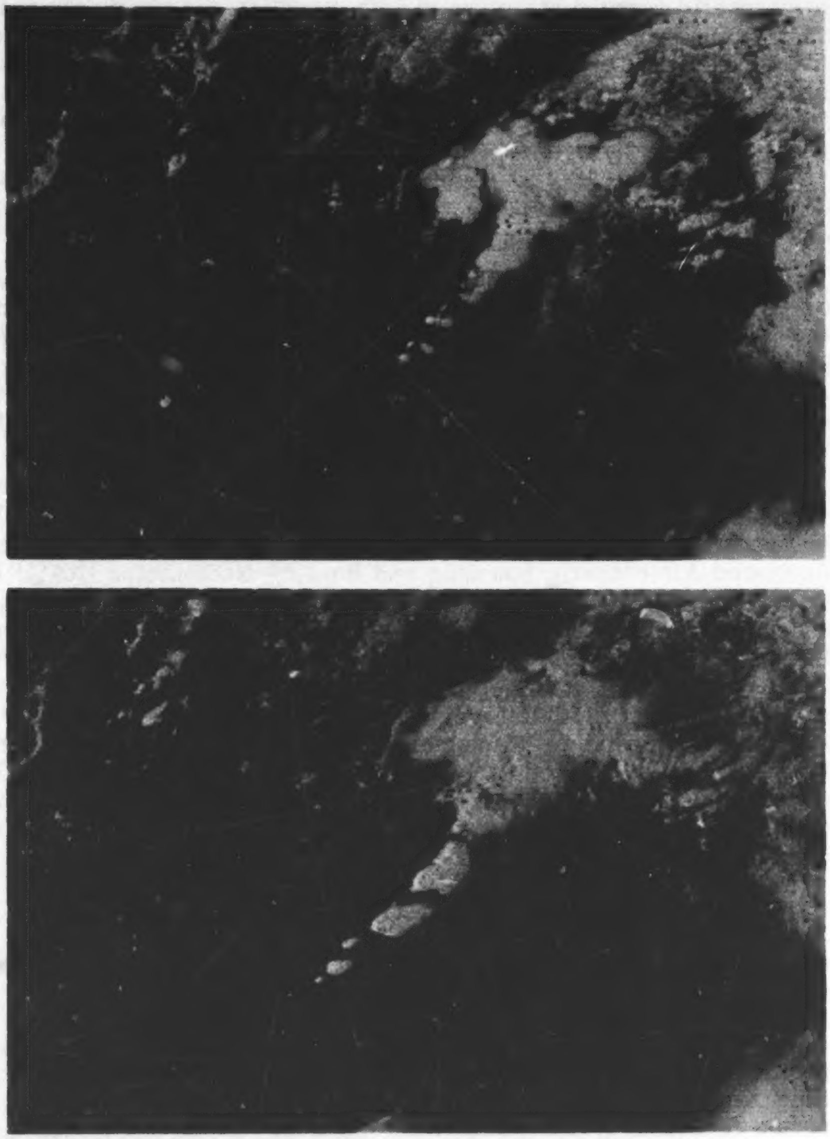


This series of GOES images at 1/2 mile resolution and hourly intervals illustrates the development of a line of severe convective storms at the boundary of moist and dry air. The moist air is located in the lower left corner and orginated over the Gulf of Mexico.

Research and Development Satellites

The National Aeronautics and Space Administration's development of experimental meteorological satellites and associated sensors will continue to improve and expand the

NASA
($25,826,000)



The line begins to form in South-Central Oklahoma (upper left) at 1300 EST on May 26, 1977, and extends throughout central Texas at 1000 EST (lower right). During The Global Weather Experiment, at least four satellites with capabilities similar to GOES will be operated by the United States, ESA and Japan, giving global coverage between 60 degrees North and 60 degrees South latitudes.

capabilities of the present national operational system. Data acquired from the experimental satellites provide essential information for research and operational meteorological purposes and will support the observational stages of the FGGE.

NIMBUS 6 is a test bed for new infrared and microwave instrumentation that should improve the determination of the atmospheric vertical structure in both cloudless and cloudy regions. This sun-synchronous, polar-orbiting spacecraft carries meteorological experiments consisting of scanning mappers, atmospheric sounders, and earth radiation balance sensors. Instrumentation for locating and collecting data from in-situ sensors will continue to support GARP through FGGE.

NIMBUS G, with a planned launch in 1978, is a multidisciplinary satellite serving the application areas of pollution, oceanography, weather, and climate.

The Sea Satellite (SEASAT) spacecraft will be dedicated to ocean dynamics applications. Its mission will be to demonstrate the feasibility of acquiring data applicable to monitoring and predicting physical ocean phenomena. Functional and environmental testing of the satellite will occur during the first half of FY 1978 with a launch scheduled for the second quarter of FY 1978.

Spacecraft definition and ground-system design have been completed for the 3-axis stabilized Storm Satellite (STORMSAT) spacecraft. As it is currently defined, STORMSAT will carry the Advanced Atmospheric Sounding and Imaging Radiometer (AASIR) instrument. Design studies have been completed for the AASIR instrument, which will be a second-generation radiometer based on the technology of the SMS/GOES visible and Infrared Spin Scan Radiometer (VISSR) and the VISSR Atmospheric Sounder instrument on GOES D. STORMSAT will also carry the Microwave Atmospheric Sounding Radiometer (MASR); design studies for MASR will be completed early in FY 1978. Efforts during FY 1978 will continue to concentrate on definition of ground data analysis techniques and mesoscale atmospheric model development. Final spacecraft system design will begin late in FY 1978.

Supporting Research and Technology ■

DOC
($5,574,000)
NASA
($36,000,000)

Major emphasis in supporting research is on deriving the quantitative information needed to develop new techniques for using satellite data. Specific programs involved are hydrology, marine forecasting, and weather forecasting. Encouraging results have been achieved in assessing the ocean environment for increasing fish yields, sea-ice surveillance on the Great Lakes and the oceans, ocean dynamics studies, and soil moisture and snowpack assessment.

Forecasting oceanic surface weather conditions is hampered by a less than adequate number of observations from ocean areas. Environmental satellites have the potential to alleviate this situation. SEASAT A, the first satellite developed primarily to observe oceanic surface conditions, is scheduled for launch in the spring of 1978. It is estimated that SEASAT A will provide the equivalent of 20,000 to 80,000 ship reports of sea-surface temperature each day. NASA is committed to developing the satellite and its sensors and placing it into orbit. When the satellite begins transmitting data, the program will become quasi-operational at the Fleet Numerical Weather Central Monterey, California, and will undergo evaluation for one year.

The Department of Commerce will continue its efforts to improve the application of satellite data to environmental warning and forecast preparation. Emphasis in this effort is on developing global atmospheric and constituent profiling systems that can be utilized in numerical weather prediction models. Oceanographic and hydrologic sensors are also being developed for use on space and aircraft platforms to measure sea-surface temperatures, to outline sea-ice distribution, and to assess snow-pack and soil moisture content.

NASA research and development efforts in FY 1978 will continue in sensor development, sensor evaluation, and analysis and

NOAA scientists and others are working together to perfect the use of new Doppler Weather Radars to identify tornado-bearing severe storms and to apply this capability in a new generation of operational weather radars. Here a team of forecasters from NOAA's National Severe Storms Laboratory (NSSL), National Weather Service (NWS), and USAF's Air Weather Service are shown advising the NWS Oklahoma City Forecast Office of tornado signatures.

interpretation to extend the capabilities for measuring environmental parameters. Satellite observations will be applied to determine such meteorological phenomena as location of rain areas; vertical distribution of atmospheric temperature, humidity, and ozone; and cloud motions (winds) from geostationary satellites. The prime objective of this research is to establish a basis for specifying remote sensing needs of the global meteorological observing system required for both large-scale, long-term weather forecasts and short-term forecasts.

Sensor development is directed toward early identification of severe storms and the measurement of such parameters as atmospheric structure and composition, aerosol content, and surface conditions -- including soil moisture, ice and snow cover, and sea state. Efforts to develop an operational geostationary imager/sounder capable of imaging and profiling mesoscale weather phenomena and an operational microwave temperature sounder for the next generation polar-orbiting satellite will continue during FY 1978. These sounders will improve the accuracy of temperature profiles retrieved from infrared soundings under partly cloudy conditions and will also permit soundings in the lower troposphere in the presence of extensive clouds.

Part of the NASA effort in sensor development for research spacecraft will be directed toward a geostationary 3-axis stabilized sounder/imager. Three-axis stabilization in geostationary orbit affords advantages that permit important improvements in sounding and imaging capability over that of a spinning instrument. Additional efforts are directed toward the development of advanced passive microwave radiometer technology for global surveillance of storms to determine such parameters as precipitation rate, liquid water content, and cloud height and structure.

The space shuttle program will influence and guide other flight missions in the near future. Studies to determine the optimum use of the space shuttle for meteorological applications will continue during FY 1978.

Stratospheric applications in FY 1978 will focus on the needs for monitoring the nitrogen-ozone and halogen-ozone chemical cycles. This work will be further supported by special sounding rocket launches as well as those from the standard meteorological rocket network. Studies will continue on post-NIMBUS G pollution monitoring tasks using the spacelab. Second-generation multigas sensors, especially the Laser Heterodyne Spectrometer and the Measurement of Air Pollution by Satellite instruments, will be evaluated on local and urban scales as a part of the tropospheric program. Regional pollutant dispersion models will be coupled to global circulation models in support of future satellite missions.

4. Fiscal Summary

The United States has planned activities for FY 1978 in all major areas of the World Weather Program-World Weather Watch, Global Atmospheric Research Program, and Systems Design and Technological Development. Funding by various Federal agencies in these three areas is summarized below. Values shown indicate outlays for FY 1977 and amounts requested in the President's budget for FY 1978. Funding is categorized as either direct (specifically in support of the World Weather Program) or indirect (primarily for other agency needs, but also fulfilling a World Weather Program need).

(Thousands of Dollars)

		FY 1977		FY 1978	
		Direct	Indirect	Direct	Indirect
World Weather Watch	[illegible]		[illegible]		[illegible]
Implementation	DOS	1,500		2,000	
	DOT		4,761		
	NASA		13,100		7,100
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Global Atmospheric	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Research Program	DOD		1,040		[illegible]
	DOT		200		
	EPA		6,000		[illegible]
	ERDA		3,479		3,514
	NASA	6,000	9,800	8,000	[illegible]
	NSF	[illegible]	[illegible]	10,850	10,100
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Systems Design and	[illegible]		[illegible]		[illegible]
Technological	DOD		245		1,000
Development	DOT		2,451		[illegible]
	ERDA		109		[illegible]
	NASA		70,200		[illegible]
	NSF	173	180	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
All Agencies	DOD		1,285		[illegible]
	DOT		7,[illegible]		[illegible]
	DOS	1,500		2,000	
	EPA		6,000		[illegible]
	ERDA		[illegible]		[illegible]
	NASA	[illegible]	[illegible]	[illegible]	[illegible]
	NSF	[illegible]	[illegible]	[illegible]	[illegible]
	GRAND TOTAL	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX-LIST OF ACRONYMS

AASR	Advanced Atmospheric Sounding and Imaging Radiometer
AFOS	Automation of Field Operations and Services
AHOS	Automatic Hydrologic Observing Station
AIDS	Aircraft Integrated Data System
AMOS	Automatic Meteorological Observing Station
AMTEX	Air Mass Transformation Experiment
APT	Automatic Picture Transmission
ASDAR	Aircraft to Satellite Data Relay
ATS	Applications Technology Satellite
BOMEX	Barbados Oceanographic and Meteorological Experiment
CDC	Climate Diagnostic Center
DOC	Department of Commerce
DOD	Department of Defense
DOS	Department of State
DOT	Department of Transportation
DST	Data Systems Test
EPA	Environmental Protection Agency
ERB	Earth Radiation Budget
ERDA	Energy Research Development Administration
ESA	European Space Agency
FGGE	First GARP Global Experiment
GARP	Global Atmospheric Research Program
GATE	GARP Atlantic Tropical Experiment
GDPS	Global Data Processing System
GFDL	Geophysical Fluid Dynamics Laboratory
GISS	Goddard Institute for Space Studies
GOES	Geostationary Operational Environmental Satellite
GOS	Global Observing System
GTS	Global Telecommunications System
ICAO	International Civil Aviation Organization
ICSU	International Council of Scientific Unions
ICWWP	Interagency Committee for World Weather Program
IGOSS	Integrated Global Ocean Station System
INDEX	Indian Ocean Experiment
IOC	Intergovernmental Oceanographic Commission
IPF	Intergovernmental Panel on the FGGE
ISOS	International Southern Oceans Studies
ITOS	Improved TIROS Operational Satellite
JMOF	Joint Meteorological Observing Facility
JOC	Joint Organizing Committee
LIDAR	Light Detection and Ranging
LUT	Local User Terminal
MASR	Microwave Atmospheric Sounding Radiometer
MONEX	Monsoon Experiment
MTC	Main Trunk Circuit
NASA	National Aeronautics and Space Administration
NAVAID	Navigational Aid
NCAR	National Center for Atmospheric Administration
NMC	National Meteorological Center
NPC	National Processing Center
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
PEB	Prototype Environmental Buoy
POLEX	Polar Experiment
RMC	Regional Meteorological Center
RTH	Regional Telecommunication Hub
SAS	Scandinavian Airlines System

SEASAT	Sea Satellite
SMS	Synchronous Meteorological Satellite
SOP	Special Observing Period
STORMSAT	Storm Satellite
TIROS	Television Infrared Observing Satellite
TCLB	Tropical Constant Level Balloon
TWERLE	Tropical Wind, Energy Conversion, and Reference Level Experiment
UCLA	University of California at Los Angeles
UN	United Nations
UNEP	UN Environment Program
USSR	Union of Soviet Socialist Republics
VAP	Voluntary Assistance Program
VISSR	Visible and Infrared Spin Scan
WDC	World Data Center
WMC	World Meteorological Center
WMO	World Meteorological Organization
WWW	World Weather Watch